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## THE GEOLOGY OF THE COMPOSTELA-DANAO COAL FIELD.

By WARREN D. SMITH.

*(From the Division of Mines, Bureau of Science, Manila, P. I.)*

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## INTRODUCTION.

The Island of Cebu shows outcrops of coal in almost all portions of its area. Abella in his "Descripción de Cebú"[1] cited as many as fifteen localities scattered from one end of the island to the other, and on both coasts. Some desultory mining has been carried on near Mount Uling, in the barrios of Lutac, Alpaco and Guilaguila, but the most serious undertakings in the colliery line were the workings at Licos and Camansi in the region behind (west of) Compostela and Danao, on the east coast, about 50 kilometers north of the city of Cebu. The last active work in this field was done in 1895, for the insurrection broke out in 1896, and since the American occupation no production has been recorded, although diligent exploration and development has been resumed.

A topographic and geologic survey of the Compostela, Danao and Carmen areas was undertaken in the early part of 1906 with the intention of aiding in this work. The area which is mapped comprises approximately 100 square kilometers (36 square miles) and is indicated by the rectangular space marked on the index map. (Map I.) Messrs. Goodman and Ickis executed the topography, using transit and stadia, their work being tied to the Liloan light-house, the position of which has been closely determined by the Coast and Geodetic Survey. I was engaged in mapping the geology during the months of December, January and February; in this work I was assisted during the latter portion of the time by Mr. Goodman.

The difficulties attendant upon all tropical work have made it impossible to indicate as many details as we desired to. The two great obstacles to geologic work in Cebu are the exceptional growth of cogon grass and the very thick formation of talus. Outcrops consequently are not sufficient in frequency to allow of accurate correlation of many of the strata. If the latter were undisturbed, or even approximately so, as is the case in horizontal formations, we might infer that what we found to be true in one part of the field would hold in all parts, but in Cebu we have found such serious disturbance, the dips and strike of the beds changing so radically within only a few meters, that it would be extremely hazardous, save in a very general way, to attempt to predict the courses of these formations beneath the surface. During the progress of the mapping we found ourselves very rarely able to trace boundaries on the surface, but in time we came to judge of the underlying formation with fair accuracy by studying the topography and the character of the vegetation. All who have tried to do exploratory work through cogon grass and "ticbao" will agree that, even though the dense jungle of such districts as Batan Island is lacking in Cebu, nevertheless for certain features of the work the kind of country we have encountered in this work can be

[1] Abella y Casariego, Enrique: Rápida descripción física, geológica y minera de la Isla de Cebú, Madrid (1886).

just as bad. In order to run a traverse along an arroyo, the only place where there is any hope of reaching outcrops and obtaining a key to the structure, I was forced actually to tunnel my way through the vegetation with the help of natives and bolos. This will give some idea of the difficulties we encountered. In one afternoon we covered approximately one-half mile. In a way it might appear that I owe an apology for publishing anything at all on this region at this time, but I feel that even the incomplete data which I can furnish will give information which will be of some guidance to those financially interested in the field and of interest to geologists in other lands.

I shall refer readers of this paper to the work of Abella, cited above, for an account of the mining work done in Spanish days in this field; however, I shall exhibit one map which was made after his publication. An examination of his geologic map will show that he did not attempt to map the region in detail, so that we feel that the new one will be a distinct advance on what has already been done. I shall add no more in regard to the present state of exploration and development than that there are two companies on the ground who are making vigorous and honest efforts to ascertain the value of the properties. There are many interesting features in connection with the work which I would like to publish, but both companies in extending me many courtesies and showing me everything have requested that for the present at least this information be considered confidential. I wish to make grateful acknowledgments to the Bureau of Constabulary, which, through its two officials in Cebu and Capt. H. W. Hunt at Danao, rendered much assistance and showed our parties numerous personal courtesies; and to Mr. H. D. Everett of the Bureau of Forestry, for valuable forestry notes.

## GEOGRAPHY.

### GENERAL.

The area under discussion comprises a rectangular tract of about 100 square kilometers (36 square miles) of territory on the upper waters of the Cot-Cot and Danao Rivers. The eastern boundary of the district is the front, or coast, range of hills which includes Mounts Licos and Mangilao; the western is formed by the Cordillera Central, which is the long, sinuous backbone of the island. The area extends as far north as a line east and west from the *pueblo* of Cármen, while Mount Acsubing marks its southernmost extension.

### CLIMATE.

The monsoons are not as clearly marked in Cebu as, for instance, they are in Luzon. This is largely due to the fact that the mountains are not so high, nor is the width of the island sufficiently great to make conditions on one coast appreciably different from those on the other.

Tables are given below showing the monthly record of rainfall and temperature. Rainfall is not always a vital point for consideration in many temperate regions, but in the tropics, where the precipitation takes such a prominent place at certain periods of the year and at times causes such destruction, before constructing important engineering works it is absolutely necessary to know the amount of rainfall and whether it is apt to be concentrated.

TABLE I.—*Temperature and rainfall in Cebu during the year 1904.*

[Philippine Weather Bureau.]

| Month. | Temperature. | Rainfall.[a] | Number of days. | Maximum in one day. |
|---|---|---|---|---|
| | °C. | mm. | | mm. |
| January | 25.8 | 327.5 | 23 | [b]180.8 |
| February | 25.7 | 48.5 | 11 | 20.6 |
| March | 26.7 | 78 | 9 | 40.4 |
| April | 27.1 | 145.2 | 13 | 63.8 |
| May | 27.6 | 158.6 | 13 | 40 |
| June | 27.2 | 178.1 | 15 | 48.3 |
| July | 27.4 | 92.8 | 6 | 63 |
| August | 27.2 | 156.4 | 17 | 36.1 |
| September | 26.5 | 116.1 | 16 | 24.9 |
| October | 26.4 | 145.1 | 20 | 25.6 |
| November | 26.1 | 149.1 | 10 | 50.3 |
| December | 25.8 | 50.7 | 12 | 15.5 |

[a] Total for the twelve months, 1,646.1 millimeters, or 64.81 inches.
[b] Or 7.12 inches.

TABLE II.—*Temperature and rainfall in Cebu during the year 1906.*

[Philippine Weather Bureau.]

| Month. | Temperature. | | | Rainfall.[a] |
|---|---|---|---|---|
| | Mean. | Maximum. | Minimum. | |
| | °C. | °C. | °C. | mm. |
| January | 26.4 | 31.2 | 19.5 | 59.5 |
| February | 26.5 | 31.4 | 21 | 33.9 |
| March | 27.2 | 31.9 | 20.6 | 35.8 |
| April | 28.1 | 32.1 | 22.8 | 18.6 |
| May | 28.5 | 33.9 | 23.4 | 94.3 |
| June | 27.5 | 32.5 | 22.8 | 219.8 |
| July | 27.3 | 32.5 | 21.5 | 128.1 |
| August | 27.7 | 32.5 | 23 | 94.6 |
| September | 27.1 | 32.5 | 22.4 | 191.9 |
| October | 27.1 | 32.4 | 22.8 | 223.4 |
| November | 26.5 | 31.5 | 20.5 | 175 |
| December | 26.9 | 30.9 | 21.9 | 98.6 |

[a] Total for the twelve months, 1,373.5 millimeters, or 54.07 inches.

An inspection of this table will show that there are no sharply defined dry and rainy seasons. The heavy precipitation of January might in another year come in the month of May. The rainfall in Cebu, where the relief is pronounced and trees over much of the area conspicously lacking, gathers very quickly in the arroyos and in a very short time the streams attain alarming proportions and work great havoc.

### VEGETATION.

I am very fortunate in being able to make use of the excellent report of Forester H. D. Everett, of the Bureau of Forestry. His report is much more reliable and complete than any discussion I could give and therefore I have abstracted it almost in its entirety and in his own words:

Less than fifty years ago most of this hill and mountain country was covered with a good, merchantable forest, but clearing has been so rapid that now only an inferior forest remains, small in area and located on the steepest and most inaccessible slopes and peaks. The forest areas are as follows, in order from the poorest to best: On the mountains of Licos, Manghilao, Pulgason, Lantauan, Donga and Uguis. Licos and Pulgason are near the mines of the Insular Coal Company, but the others are nearer and more accessible to the mines of J. G. White & Co. On the west side of the main divide of the island and tributary to the Balamban River are the forests of Sacsac, large in area and in good condition, but practically inaccessible from the east.

*The forest of Mount Licos.*—Mount Licos is a long, narrow ridge extending from Camansi to the Compostela mines, reaching a height of 1,750 feet above the sea. Only its top and steepest rocky slopes, which can scarcely be climbed, have any tree growth and this is small and scattered. It is mapped as noncommercial. Almost no trees of the better species grow there, although twenty years ago a considerable quantity of good timber was secured in this place. Almost no timber can be obtained for the mines. A few pieces for temporary work of inferior kinds can possibly be cut.

Although this forest is small and in a deplorable condition, if it were protected from cutting and *caiñgins* (forest clearings) for some years, it would probably recover. The land is only fit for forest use.

*The forest of Mount Pulgason.*—Mount Pulgason is a large mountain with many radiating ridges most of which are covered with cogon or small brush. Many *caiñgins* cultivated to corn are on its slopes. The forest is located on the top and in some of the draws near the top, on both the east and west sides. Some of this may be considered as merchantable, although it has been cut over for many years by the licensee, Ambrosio Lao. It is evidently by his efforts that so much of this forest has been preserved from destruction by *caiñgins*, since the slopes are not very rocky and *caiñgins* could easily be made.

The forests have a denser stand, larger trees and better species than on Mount Licos, yet nevertheless they are in a poor condition, being characterized by small trees and scattered growth. The species are mostly unknown small trees

with aluan,[2] sambulauan, and a little narra and amaga. The narra and amaga are small trees and scarce.

*The forest of Mount Manghilao.*—Mount Manghilao is part of the coast range of hills and lies close to the towns of Danao and Carmen, showing prominently. Its elevation is about 2,250 feet above the sea. The remaining forest rests on the rockiest part of the top and partly down the rocky slopes, which in places are cliffs. The forest has been subjected to excessive cutting in the past and to considerable destruction by *cainginș*. It is a tangle of vines, saplings and small trees with a few scattered large trees of lauan, manaog, nipot-nipot and nato. There are present, as in all of these mountains, a large number of tree species, few of which are valuable. A part of this forest may be called merchantable here, although in better timbered regions it would be nonmerchantable. First-group trees are practically wanting. What is really called for in this forest is absolute protection for many years.

*The forest of Mount Lantauan.*—This mountain is a sharp peak of volcanic rock, so rocky and precipitous that some good timber still remains because it is so difficult to cut. In places the forest is fairly dense and of good sized trees, chief among which are white lauan, duca, nato, maobog, lanete, narra, bagtican and ditaa. On this mountain considerable mine timber can be cut without serious silvicultural damage to the forest.

[2] List of tree species with native and botanical names mentioned in Mr. Everett's report:

| | |
|---|---|
| Agusahis | =*Ficus* sp. |
| Amaga | =*Diospyros* sp. |
| Amahuyan | =*Dysoxylum* sp. |
| Bagtican | =*Shorea* sp. |
| Betis | =*Illipe betis* (Blco.) Merr. |
| Bogo | =*Garuga floribunda* Dcne. |
| Camungayon | =*Aglaia* sp. ? |
| Datilis or caballero | =here refers to *Leucœna glauca* Benth. |
| Ditaa or dita | =*Alstonia scholaris* R. Br. |
| Duca | =*Cynometra* sp. |
| Duñgon (bayog) | =*Tarrietia sylvatica* Merr. or *Pterospermum* sp. |
| Dungula | =*Vitex aherniana* Merr. |
| Guijo | =*Shorea guiso* Bl. |
| Hambabæ | =*Nauclea* sp. or *Randia* sp. |
| Lanete | =*Wrightia* sp. |
| Lauan | =*Shorea* sp. |
| Manaog (balacbacan) | =*Shorea* sp. |
| Mata-mata | =*Aglaia* sp. |
| Moabog | =? |
| Molave | =*Vitex* sp. |
| Nancaon | =? |
| Narra | =*Pterocarpus* sp. |
| Nato | =*Palaquium* sp. |
| Nipot-nipot | =*Gleditsia rolfei* Vid. ? |
| Pagolingan | =*Cratoxylon floribundus* F. Vill. |
| Pagsagon | =*Mimusops elengi* L. |
| Pili | =*Canarium* sp. |
| Putian | =*Aglaia* sp. |
| Quia-quia | =? |
| Sambulauan (amuguis) | =*Koordersiodendron pinnatum* (Blco.) Merr. |
| Taguilumboy | =*Eugenia* sp. or *Cynometra* sp. |
| Tindalo | =*Pahudia rhomboidea* Prain. |
| Tunguatingan | =*Nauclea* sp. |
| White lauan | =*Shorea* sp. |
| Yacal | =*Hopea* sp. |

*The forest of Mounts Uguis and Donga.*—Mount Donga is really a foothill of the higher mountain or ridge called Uguis. The upper slopes and tops of these mountains are fairly well wooded and have suffered less from cutting than the other mountains. This is due to the fact that they are farther from Danao and that their steep slopes, covered with huge volcanic bowlders, make logging extremely difficult and in places impossible. However, mine timbers could be cut on these slopes and skidded out by hand at a considerable expense. It is probable that timber could be imported from other islands at less expense than it could be secured on this mountain, except in famine years when the people work very cheaply.

Uguis and Donga have a fair sprinkling of narra, bagtican, amaga, lanete and dungon among the many inferior species which are also present.

*The forest of the Sacsac River.*—An extensive virgin forest exists across the main divide of the island and tributary to the Balamban River, containing large trees of lauan, sambulauan, quia-quia, narra, pili, bagtican and other timber species. Bejuco (rattan) also grows in this forest in fair abundance. At present the forest is inaccessible from the east, but it is barely possible that at great expense, yet not a prohibitive one, a road could be made up the Uguis stream and across the divide by which this timber could be brought to the Danao River and thus to the mines.

Cutting rules, copies of which have been sent to the three licensees, are based on the following facts and conclusions:

(1) In these forests it is possible to secure only a small part of the necessary mine timber from first-group trees.

(2) There are some species of the lower groups which will serve fairly well, especially for temporary work.

(3) The cutting of small trees of the first and second groups in these forests will exterminate those species.

(4) It will be necessary to import timber from other regions for the proper, future development of the mines.

(5) The future development of the mines will double the demand for timber.

(6) The trees at present being cut are small with an average diameter of not more than 25 centimeters.

(7) The forests, especially those of Licos, Pulgason and Manghilao, are in very poor condition.

*Use of timber in the coal mines.*—Timber was used in former times and is needed at present in the form of ties for the tramway leading from Camansi to Danao and as posts, caps and lagging for the tunnels. The company which operated the mines in Spanish times used mostly the most durable timber of the first group such as molave and tindalo, both for the tramway and for the tunnels.

*Old timbers of the Compostela mines.*—Most of the timbers were placed in these mines in the years 1895 and 1896. They consist for the greater part of molave, tindalo, yacal and narra, with a few of the inferior or little known species which grow in the neighborhood. The lagging was made of poles of datilis or caballero. Some of the old tunnels are now being cleared out and new timbers put in where the old ones are no longer serviceable. Up to the present time not more than 40 per cent of the old posts and caps have been removed in the Enrique Abella tunnel. Many of the molave timbers are perfectly sound after about twelve years of service. The following specimen sections were taken from some of the old timbers at the ends where they were in contact with the soil.

*No. 1.*—Pagsagon post, sound with the exception of about one centimeter on the outside and one bad knot which had weakened the post.

*No. 2.*—Betis (?) post, in good condition.

*No. 3.*—Guijo cap, badly rotted at the ends.

*No. 4.*—Pagsagon post, fairly sound but weakened.

*No. 5.*—Tindalo post, affected in spots but fairly sound.

*No. 6.*—Bogo post, affected in spots so as to be useless.

*No. 7.*—Molave post, slightly affected so as to be weakened.

*No 8.*—Molave cap, fairly sound with hollow at the heart which was probably there originally.

*No. 9.*—Tindalo cap, still useful.

*No. 10.*—Nipot-nipot cap, badly rotted.

*No. 11.*—Putian (?) post, slightly affected at heart.

*No. 12.*—Taguilumboy post, still fairly sound and could serve for some time longer.

*No. 13.*—Nancaon post, in fair condition.

The above timbers have seen ten to twelve years' service. In general, the caps are affected by decay sooner than the posts.

A large proportion of the inferior or little known woods of the locality were used in the Camansi mines. Some of them have proved to be very durable, almost as much so for the purpose as molave. These are most notably taguilumboy and hambabæ. Putian, camungayon, nancaon, mata-mata, tunguatingan, and amahuyan have shown themselves to be fairly satisfactory.

The conditions affecting the durability of the mine timbers are different from those influencing an *harigue* (house post) or other timber exposed to light and air; they are in almost complete darkness, are constantly dripping with moisture and are covered with slime. The air inside the tunnels is heavy, hot, laden with moisture and it varies but little in temperature. The white ant is said not to work, except at the entrance to the tunnels, and no injurious work of insects was observed in the old timbers. Consequently, conditions are not such as to cause the most rapid decay, although favorable to the growth of destructive fungi.

*Present use of timber.*—The wood used in the mines is in the form of posts, caps and lagging. For 100 meters of tunnel 170 caps, about 7,000 short stakes for lagging and 340 posts are used, having an approximate volume for posts and caps of about 20 cubic meters. The lagging used is formed of the small stems of the datilis or caballero, a brushwood growing in thickets near streams, which does not make a timber tree.

The caps are about 1.35 meters in length and 0.50 in circumference; the posts about 2.35 by 0.55 meters. They are entire, round logs, cut from small trees and are not treated in any way to preserve them from decay. A coal-mining operation on a fairly large scale would run about 1,500 meters of tunnels a year, which would require about 300 meters of timber for posts and caps, exclusive of that used for the tramway and for general construction. This would mean about 2,000 small trees to be cut to about the size now being used.

Since work is now progressing only on a small scale, old tunnels being cleared and a few new ones started, at present but a small amount of timber is required. This demand can be supplied for a time by the neighboring forests, but as soon as the operations are greatly extended it will be necessary to secure material from other sources.

*Possible sources.*—It is probable that rejected railroad ties can be obtained which should make good mining timbers. The dungula growing on the tract of the Insular Lumber Company should be a most excellent mine timber. This is now being cut and doubtless, from time to time, a steamer load could be secured. The better forested islands, such as Mindanao, Samar, Paragua, and Mindoro, should be a source for mine timbers of the first group. Only further experience

and observation will show how durable for the mines are the many, little known timbers of the Islands. Some of these will undoubtedly prove to be very satisfactory.

It is probable that in time it will be practicable and advisable to treat mine timbers with preservatives, in this way using the most abundant and cheaper kinds. Painting timber with the preservative or giving the timber an open bath treatment will be found the cheapest methods. In this connection, attention is called to Press Bulletin No. 141, November 27, 1906, United States Forest Service, "Prolonging the Life of Mine Props."

POPULATION MARCH 1, 1907.

The Filipinos inhabiting this island are called Visayans and are, save for minor differences in dialect, the same as the people of Leyte, Negros and Panay.

As I have pointed out in my previous paper,[3] the greater part of the population and also that portion which belongs to the better educated class, is confined to the narrow coastal tract in the towns of Carmen, Danao and Liloan, and others and to their outlying barrios. The dwellers in the hill country are extremely poor, when their state is compared with our manner of living or even the mode of life of the people of the coastal plain. Corn is their chief staple. I believe this dominant corn diet is peculiar to the *Cebuanos*. The *ilustrados* largely control the fertile cove areas in the intermontane tracts.

The peasant of Cebu is very superstitious. As an instance of his ignorance and credulity I may cite one rather remarkable case, which, however, at one time came very near to not having an amusing aspect. In our trips here and there over the field we were obliged to pass by many native houses and near the end of the work we were surprised to find the children all running away from us, or their mothers would quickly hide them as soon as we came in sight, a thing which had never been done in this district on previous visits. This continued for some time, with also an increasing surliness on the part of the men. Finally, an engineer of one of the coal development companies was stopped late in the evening when he was some distance from camp. The natives proved themselves to be in a hostile mood and as they had *bolos* (long knives) and one or two spears he felt warranted in drawing his side arm to protect himself and not until the *teniente* of the local *barrio* appeared and explained in Spanish, did he learn the cause of their attitude. It seems that some malicious person or persons had played upon the credulity of the people, making them believe that the Americans were stealing the children in order to kill them and let their blood drop on the ground, this being a supposed means of ascertaining where the coal was. It took some days to eradicate this belief from the minds of the peasants and

[3] "Contributions to the Physiography of the Philippine Islands: I. Cebu Islands." *This Journal* (1906), 1, 1043.

for a time it kept the local Constabulary force doing guard over the several camps. This is the only incident of the kind which has ever been brought to my attention in the Philippines and I consider it altogether exceptional.

HYDROLOGY.

The area under consideration is well drained by two fair-sized streams, the Danao and the Cot-Cot Rivers, which become raging torrents in rainy weather, but quickly subside, and in the dry season are so shallow that not even the smallest *bancas* can navigate them. The generally deforested condition of the region is responsible for this condition.

TOPOGRAPHY AND PHYSIOGRAPHY.

The general appearance of this country is mountainous although in reality the highest point, apart from the *Cordillera Central* is not over 685 meters (2,245 feet). The reason for the exaggerated topography is the pronounced relief which is due to two main causes, first, the folded and warped condition of the rocks, and second, the absence of forest, which gives the meteoric waters a free field to do their work of dissection. The absence of forest is also a factor in making visible at a glance even the minutest topographic features, whereas in countries with a heavy forest mantle much of the relief would not be seen.

The topographic features of this region are as follows: 1. The quite complete dissection of the country. 2. The long, limestone-capped ridges of Mounts Licos, Manghilao and Lantauan. 3. The rather unconventional orientation of the drainage. 4. The change of topography with change of formation.

In a previous paper,[4] I have spoken of the intermediate uplands of this island. They comprise all of the elevated tract between the coastal plain, with the low coast hills, and the *Cordillera.* They are largely underlaid by limestone. Corn is the principal product. The people, while apparently very poor, nevertheless are satisfied and have all they need. They form the most peaceable portion, by far, of the native population.

In the terms of the modern science of physiography this region is in maturity, namely, it is in such a condition that a little less denudation or a little more would decrease the relief and make all the outlines less pronounced. Further denudation, unaccompanied by elevation or warping, would cause the region to pass into "old age."

The most striking topographic features are the limestone-capped ridges of Licos, Lantauan, and Manghilao. The limestone being more resistant than the underlying shales and soft sandstone, has protected certain areas between the master streams and hence the highest points are of the

[4] *Loc. cit.*, 1043.

former material. This limestone does not conform to the beds below, but lies as a mantle upon the folded and truncated coal measure beds, and in some cases upon igneous formations. However, there is a decidedly warped appearance to this formation which is in part due to the configuration of the older topography upon which the limestone was laid down, and also to some minor folding subsequent to its deposition.

A somewhat noteworthy feature of the drainage is the orientation of the Cot-Cot and its tributaries, the Jimarco, the Parel and the Muao; and the peculiar course of the Danao.

The Cot-Cot and its three tributaries are seen to conform with reasonable closeness to two lines which make an angle of 92° with one another. The Jimarco and the Cot-Cot fall on a line the course of which is N. 37° W., while the Muao and the Parel come into the main stream approximately at right angles or along a line N. 55° E. I am strongly of the opinion that the N. 37° W. line is a fault line, although I have no other cause to think so than its great persistence.

Side branches under normal conditions do not join the trunk stream at right angles, but always in such a manner as to make an acute angle upstream with it. The reason for this departure in this region lies in the structure of the underlying formations. In a traverse of the Muao, in more than one place, I found that the strike of the beds conformed to the direction of the stream and there should be little doubt but that this factor has controlled its course, as it would be much easier for the stream to cut along this line than across the formations. As the dip is generally to the southeast throughout the greater part of this region, it would be expected that the stream would shift laterally and in the direction of the dip.

I am not so certain that this holds true in the case of the Taganejan, as exposures of the sedimentaries are not so plentiful. If we now examine the course of the Danao, the headwater tributaries of which are known as the Cajumayjumayan and the Donga we see that it starts on the northeast slope of Mount Lantauan and flows southwest in the Cajumayjumayan basin until it strikes the *Cordillera,* it then swings to the south at the base of this ridge and turns rather sharply to the southeast, worming its way in great curves through a cañon-like cut in the basal igneous formation, and still farther down it takes a due easterly course to the sea.

As the Cajumayjumayan Valley is a syncline, the river in this part of the course is a consequent stream. In time the courses of Donga and Cajumayjumayan Creeks will coincide, as both shift laterally along the dip. That part of the stream which lies between Sibacan and Ustaganon Creeks is antecedent. Its present incised meanders in that portion are evidently inherited from an earlier and higher stage of the stream, and may point to a post-Miocene peneplain.

I found that the courses of the Mantija and Mangliji side streams were almost entirely controlled by structural conditions. As can be seen by a cross section of almost any part of the field, the coal measures are folded to a considerable degree in some places. The Magliji is located on the crest of a small local anticline and the reason for this position is that there is usually along the crest of an anticline a fracture system which would give a stream a foothold.

It would be interesting to know to what extent jointing and faulting had affected the orientation of drainage in this area, but unfortunately there are few good exposures, and quarries and mining operations have not yet proceeded far enough to throw much light on the underground condition.

To one accustomed to read topographic features much of the underlying structure and formations of a country is revealed, whereas to another person a surface examination would disclose nothing. For instance, the abrupt change in the contours at the point where the Ustaganon comes into the Danao should be noted; west of that point the rock is igneous, a hard, fairly structureless diorite, east of that point to a place as far as the end of the railroad, the contours are fewer and farther apart, showing gentle slopes and outlines, the underlying formation is that of the coal measures, consisting largely of soft shales. Again, the crowded contours just south of the end of the railroad track at Camansi should be considered. They mark a great, white cliff of limestone, which usually gives this character to the topography. I may state that such topography is not very favorable to engineering projects.

## GEOLOGY: GENERAL.

For purposes of convenience, and also because of a natural distinction between the areas, I shall treat the geology of this region under the following heads:

1. The Acsubing-Muao region.
2. The Mount Licos region.
3. The Cajumayjumayan region.
4. The Sili Creek region.

### THE ACSUBING-MUAO REGION.

This portion of the district, lying south of the Cot-Cot River, is largely covered by a sheet of andesite and it therefore is much more simple to deal with. Although this part of the area was evidently entirely covered by this sheet of andesite, the streams have greatly dissected it, cutting down through it for over 200 meters (nearly 700 feet) to the unconformable coal series below. Isolated residual patches of the upper limestone are scattered at long intervals, resting upon the andesite.

The streams are naturally for the greater part deeply incised with V-shaped cross sections as a result of the character of the formation which is predominantly igneous.

PLATE I.

Although the region is maturely dissected, it may be seen that the majority of the hilltops come up to a common plane which does not signify a peneplain, but simply the surface of the great lava flow which just antedated the deposition of the Miocene limestone.

This section is very rugged and at first sight quite forbidding. The larger part of the people live in barrios and reconcentration camps on narrow ridges. These camps were established in 1903 and 1904 by the Constabulary to protect the people from some bands of "pulajanes" infesting the country at that time. Although at first sight the country would appear to be barren and unproductive, the wash from its decaying limestone and the disintegrated andesite produce a fairly rich soil. I have seen some very good corn in this section. Plate I is a view of the Cot-Cot country which very well shows the general appearance of this dissected Tertiary lava field.

The most widespread formation is a porphyritic rock which will be described at greater length further on. In many hand specimens it is clearly an andesite, with feldspar and pyroxene phenecrysts in a fine groundmass; in others, all which can be seen are white feldspars (usually kaolinized) in a fine-grained, green groundmass.

A series of shales, sandstones and graywackes are found to be exposed where the streams have cut down through this lava capping, where the talus is not too thick, dipping sometimes at high angles and with constantly changing strikes. It would be highly advantageous to be able to map these, giving their underground courses, but the outcrops are not sufficiently numerous or contiguous to do this with any assurance of safety.

There has been some mineralization in the vicinity of Acsubing Mountain, as galena is found in veins in the andesite. We have been able to see these veins only in two localities, but these limited observations led us to believe that the deposits are in the form of a *"stock work."*

I have been unable to find any coal in this series, nor have I encountered any fossils, but I have no reason to doubt that the series belongs to the coal measures. A portion of it may be terrestrial in origin, as seems to be the case with the formations to the north of the Cot-Cot and the east of Mount Licos.

### THE MOUNT LICOS REGION.

This includes both the old Compostela and the Camansi workings and was the principal field in Spanish days. This portion of the district is quite different from the preceding, in that the igneous extrusives are lacking over most of the territory. As the western part of the field abuts on the igneous basement complex, in our mapping we have kept well to the east. By referring to the map, a belt which widens and narrows (represented by the blue color) may be seen; in general it runs in a northeast-southwest direction. This is the productive portion of the coal

measures; to the east it dips beneath the limestone and still farther to the east it undoubtedly would be found, although at no inconsiderable depth. This belt of productive measures can readily be traced in a general way by the topography and the vegetation. The topography is marked by moderate, gentle slopes and rounded contours. The vegetation consists largely of rank *cogon* and *talâhib*, with absolutely no forests.

Mount Licos is a long, irregular mountain the highest point of which is just above the Compostela workings. From its height of 520 meters (1,700 feet) it declines gradually to the northeast to the Danao River. This eminence is capped with a white, orbitoidal limestone of 30 to 150 meters (100 to 500 feet) in thickness. This capping is very rugged, exceedingly conspicuous and easily traced; it is fairly well, but not densely, clad with forest trees. To the north of the mountain we find a great mass of conglomerate, not basal, but such a formation as is characteristic of coal fields. I have called this the barren measures. Its thickness is at least several hundred feet, although just how great it is I am unable to say. Although it is treeless, it is marked by its accentuated relief. This formation will be treated of more fully in a subsequent portion of this paper.

### THE CAJUMAYJUMAYAN VALLEY.

Another field containing coal lies to the north of Sili Peak and Lantauan ridge. This is simply an extension of those to the south. Its structure, to judge from rather incomplete data, is that of a basin or syncline. Practically the same formations as those mentioned under the Mount Licos region occur here and in the same order. The most characteristic feature of the field is the hogback in the center of the basin, which is a remnant of the upper or barren conglomerate. There are five seams in this valley, as is the case in the others.

TABLE III.—*Stratigraphy of the Compostela-Danao region.*

| | | |
|---|---|---|
| Recent. | Alluvial deposits in streams and extensive and thick talus on all slopes; and travertine. | |
| | UNCONFORMITY. | |
| Miocene. | Upper white limestone, coralline and containing *Orbitoides*, *Lithothamnium* and many mollusca in its basal portion. | |
| Oligocene. | Shaly limestone—cream colored and soft—unfossiliferous. | |
| | UNCONFORMITY. | |
| Eocene. | Extrusive rocks—chiefly andesite. | |
| | Terrestrial deposits consisting largely of conglomerate—showing much oxidation. | |
| | UNCONFORMITY (?) | |
| | Coarse gray sandstone. | |
| | Coal measure shales including five coal seams. | 90 to 150 meters (300 to 500 feet.) |

UNCONFORMITY.

Pre-Eocene (?) Basal diorite and conglomerate.

STRATIGRAPHY.

I have compiled in Table III a statement of the stratigraphic column which gives, as nearly as I now know it, the relation of the different formations in this part of the island. Beginning with the lowest, we have the basal complex largely composed of diorite and, as a closely related part of this, the basal conglomerate. Its extension where it comes to the surface can be seen on the map, represented by the red single-cross-hatched color. It occupies a portion of its western part, in fact the map was not extended farther because of it. A typical diorite is found in the winding gorge of the Danao River, in every respect resembling the basal rock of Masbate, Benguet, etc. A typical development of basal conglomerate is to be seen in portions of the river course, while in others but little of this can be observed.

THE IGNEOUS BASE.

For some time I was puzzled by the particular phase of igneous rock constituting the hills on the left, or north side, of the Danao River. Here the rock is more of a porphyry than holocrystalline. From all the evidence I was able to procure the rock exposed on this higher ground is merely a porphyritic facies of the diorite, as would be natural to expect in the upper part of the mass, where the cooling had been more rapid. A feature of this rock is the innumerable, minute, calcite veins cutting through it without definite system.

The following is a description of this rock from the region of Sili Creek, not far from the coal measures:

CEBU NO. 5 (DILWORTH).—DIORITE PORPHYRY.

*Hand specimen.*—A dark colored, fine-grained, igneous rock. The only minerals identifiable in the hand specimen are dark green plagioclase and rare specks of magnetite.

*Microscopic (2 sections).*—The rock is composed almost entirely of feldspar, rather decomposed. There are several porphyritic crystals reaching a maximum size of 2 by 1 millimeters, but the majority are small laths. About 5 per cent of the feldspars seem to be orthoclase. No good determinations could be made of the plagioclases, but six rather doubtful ones gave three of acid labradorite and three of basic oligoclase. Many of the feldspars show good zonal structure. Several, especially among the smaller laths, are bent.

Biotite is present in all stages of decomposition, but is always well chloritized. There are no well-defined plates.

Quartz occurs in small and inconspicuous grains. It forms a very small part of the rock and is accessory rather than essential.

There are a large number of small crystals of titaniferous magnetite or limonite, generally associated with the biotite. The presence of titanium is shown by the dirty white titanite, which surrounds these crystals.

Secondary minerals are: Kaolin and sericite, along cracks in the feldspars; chlorite replacing biotite; patches of calcite; and titanite associated with the magnetite.

BASAL CONGLOMERATE.

The basal conglomerate, in some places at least, overlies the igneous basement; however, this does not appear anywhere to have the strong development it has in the Benguet region.

This conglomerate marks an unconformity, probably the greatest break in the stratigraphic column within the limits of the Archipelago, and it differs from the conglomerate in the coal measures by the fact that all the included pebbles are igneous, whereas in the case of the latter they are mixed with sandstone, shale, etc., clearly showing that they were not altogether derived from the basal mass. It would be difficult to determine the age of the basement complex, but it is certainly pre-Miocene.

In the region of Sili Creek we find a formation which, taken altogether, I call a greenstone. Some phases of this are certainly diorite, others are porphyritic, and near the head of the creek, at 380 meters (1,250 feet), there is a dark phase of rock which may be a diabase and hence a dike, but the extremely limited exposure of the outcrop prevented my being absolutely certain. A very important question affecting our knowledge of the extent of the coal on the north side of the Danao River, is whether or not this upper portion of the formation in Sili Creek might not be an intrusive or even an extrusive, like the flow south of the Cot-Cot River. We might then, in the event of this proving to be so, expect to find the coal beds below and possibly exposed somewhere in the bed of Sili Creek. Nowhere in this channel was any coal formation encountered, but on the other hand a clean section of several hundred feet of greenstone was observed.

I found the greenstone in this stream at an elevation of 238 meters (780 feet) with marked jointing, the directions and dips of which are as follows: S. 25° E., dip 60° NE.; N. 82° W., dip 76° NE.; S. 40° W., dip 40° SE.

THE COAL MEASURES.

I have divided the coal measures into two subdivisions for purposes of convenience in description, although in the field I have found no sharp line between these. The lower part of the measures consists of gray shales, the upper portion of a coarse, gray sandstone. There are five coal seams. I have mapped the slates and sandstone under one color (the blue), because it is practically impossible to separate them in the field.

The photograph (Pl. II) shows the contact of the coal measure shales with the basal conglomerate. It also shows the intense plication in the weaker rocks, where they abut on the resistant igneous base.

The shales, as this stream (the Suqui) is ascended, become more and more coarse until the coal seams are encountered where a grit appears. There are about 60 or 100 centimeters (2 or 3 feet) of clay and shale, just above the "Enriqueta" vein, then the coarse gray sandstone comes

PLATE II.

in, and from there on up to the base of the limestone all outcrops (which are very few indeed) show sandstone. This sandstone in its composition very clearly demonstrates that it was largely derived from the igneous material near at hand and we may infer that the only high land at the time of its formation consisted of the diorite and greenstone hills which stood above and immediately to the westward of the tidal swamps in which the coal was forming. We can estimate the thickness of the sandstone only approximately, but considering the outcrops on the slopes of Mount Licos, I believe it to be not over 150 meters (500 feet). It is very improbable that there is an unconformity between the shales and the sandstone. Numerous observations of the strike and dip of these formations show the strike in general to vary from N. 27° E. to N. 55° E. and the dip anywhere from 20° to 90° SE. In the region to the west of the Mount Licos workings and in the arroyos which head in or near the igneous formation, I found some westward dips at rather high angles, showing complete overturn, but this is to be expected as the igneous rock is approached.

There is every reason to believe that the limestone rests unconformably above the sandstone. This formation has two well-marked phases; the lower characterized by being softer, more of a yellowish color and so far appearing to be unfossiliferous, it also is more stratified than the upper part; the upper portion is a very white, hard, sometimes crystalline limestone, revealing little regularity of structure.

Before describing it in detail I should discuss two other formations which occur in the stratigraphic column between the sandstone and the limestone.

Both of these are terrestrial deposits—the first or lower is a conglomerate made up of igneous sandstone, shale and slaty pebbles. The very reddish-brown color of both the pebbles and the matrix, the evidence of oxidation and the general heterogeneous character of the pebbles show pretty clearly that this formation is in the nature of a flood-plain deposit, or as Professor Barrell would call it, piedmont deposit. On the map this is denoted by the brown color, and the formation is to be found extensively developed on the east side of Mount Licos. In places it is at least 90 meters (300 feet) thick, and it may be more. A remnant of it is found in the hogback in the bottom of the Cajumayjumayan Valley and in several other isolated patches above the coal. The pebbles in this formation are usually small; I saw none exceeding 2 inches in diameter.

The second terrestrial deposit of consequence in this field is the andesite just south of the Cot-Cot, the extension of which I have already alluded to. I have mapped a series with this formation, which is rather difficult to demarcate and separate from the andesite because when the two are weathered they strongly resemble one another. This series Abella alluded to as *tobas*, which means a clastic rock derived from the wear

of other rocks, chiefly igneous; we would call them graywackes. Some rocks of pyroclastic origin are also doubtless associated with these. The best place to see these graywackes is in the gorge of the Cot-Cot just above Muao, where they can be seen dipping at a low angle to the east; and above them at approximately 300 meters (1,000 feet) elevation is the andesite capping.

Petrographic descriptions of both the andesite and the detrital material made for me by my colleague, Mr. H. G. Ferguson, are given below:

CEBU NO. 45.—ARKOSE.

*Hand specimen.*—Extremely fine grained, grayish rock, the distinguishable minerals of which are pink feldspars, quartz, magnetite and occasional hornblende (?). The grains are all very small and approximately the same size.

*Microscopic.*—The rock is much decomposed, especially the feldspars. Feldspar is the most prominent mineral, and is chiefly orthoclase, but one grain of albite was found. There are no perfect crystals, but occasional crystal faces occur. Quartz is rather rare in definite grains, but seems to fill spaces between other crystals. Biotite occurs in small amounts, but in bent and frayed fragments rather than plates. Occasional fragments of hornblende crystals are present. Magnetite occurs in numerous, small grains, often partly altered to limonite. One grain of topaz (?), a few minute grains of olivine (?) and numerous very minute grains (diameter generally about 0.01 millimeter) of a mineral with high refractive index and rather high double refraction, apparently titanite, are the accessory minerals.

The rock shows no definite structure. The grains vary in size, but never exceed 0.25 millimeter and perfect crystals are never found. The biotite especially presents a fragmental appearance. I believe the rock to be an arkose, formed by the decay of a trachytic igneous rock and with only slight transportation, as there is no evidence of assortment of the minerals.

CEBU NO. 70.—ANDESITE.

*Hand specimen.*—The specimen is taken from the contact of two igneous rocks of different texture, one a greenish-gray, aphanitic rock and the other more porphyritic, consisting of greenish and glassy-white feldspars, in a purplish groundmass. The contact is a shearing plane, stained with iron oxide.

*Microscopic (2 slides, both from the porphyritic rock).*—Feldspars in idiomorphic crystals are very prominent, but are all completely decomposed, chiefly to sericite aggregates, and are also to a large extent replaced by calcite. One doubtful case of albite twinning was found, which gave extinction angles corresponding to oligoclase.

Biotite is present in considerable amount (possibly 5 per cent of the slide). This mineral is interesting as it shows different stages of decomposition. In part it has simply lost a portion of its iron content and become more hydrated, showing in plane polarized light a greenish pleochroism and under crossed nichols a much lower double refraction than normal biotite, the colors ranging from first order gray to first order yellow. For a part of the mineral, however, the alteration has been more complete and the biotite has gone over to chlorite; sometimes both stages can be observed in the same crystal. Biotite has also suffered somewhat from replacement by calcite.

Other dark silicates if originally present have been altered beyond recognition.

Magnetite is present both in large grains (largest 0.3 by 0.2 millimeter)

associated with the biotite, and in small specks in the groundmass. It is generally fresh, but rarely is somewhat decomposed, staining the surrounding portion of the slide with iron oxide.

The groundmass is for the most part a mass of cloudy decomposition products and secondary calcite. Occasional remnants of feldspar microlites can be made out. There are also numerous small rods and specks, visible only with the highest power objective. These are colorless, brown and opaque, but not clearly resolvable. Numerous small specks of magnetite also occur.

### THE UPPER LIMESTONE.

*The upper limestone* is quite hard, dazzling white on fresh exposures and the boundary of the formation is readily followed even where it happens to be covered with talus. This formation is found in more or less detached areas, it being remnants of what was most probably a continuous blanket. It rarely reveals any stratification and hence its dip and strike is generally a matter of conjecture. It is my conception that prior to the formation of this blanket of limestone there existed many irregularities in the surface, due to previous erosion, and that the limestone deposit first filled in these irregularities.

This horizon of the limestone in places is quite coralline, with many of the characteristic genera now growing in the surrounding reefs. These corals now appear to be segregated in colonies, although there may previously have been a continuous reef formation of which we have merely the remnants left, the other portion having been destroyed by erosion.

The lower part of the formation is in places very fossiliferous and the mollusca now fossilized undoubtedly lived in colonies, as we know them to do to-day. At an elevation of 275 meters (900 feet) and near the barrio of Mabasa I found a great many fossils which had weathered out of the rock. They are all casts and a number of them are in poor condition. (Pls. III and IV.) Some of the genera represented are:

| | |
|---|---|
| *Cerithium.* | *Trochus.* |
| *Fusus.* | *Bulla.* |
| *Turbo.* | *Pectin.* |
| *Natica.* | *Dosinia.* |
| *Teredina.* | *Conus.* |

It is not my intention to make this a paleontologic discussion and therefore I shall leave these fossils with the statement that I have compared them with many of Martin's illustrations in his monograph on the Tertiary of Java and have found many that I believe to be identical with those from which his illustrations are taken.

I have thought it best not to treat of the paleontology at this time, as it is my purpose later to prepare a monograph on the Tertiary fossils of the Philippines.

Foraminiferal tests can be found at nearly any point where a piece of this limestone is chipped. The genus *Lepidocyclina* (*Orbitoides*) predominates. Generally, these fossils are found most thickly near the base of the upper white limestone, they are much larger in this situation than in the upper horizons and I believe them to be of quite a different species. The two best localities in which to find these *Orbitoides* are at Mount Lantauan, near the large sink hole at the eastern end of the ridge, and at 320 meters (1,050 feet) elevation on the southwest slope of Mount Licos, where the trail passes around to the coal workings.

Another characteristic form found in this limestone is the marine alga *Lithothamnium ramossisium* Reuss. This is shown in two sections on Plates III and IV.

There seems to be little question but that this is the same horizon as the Baguio, Theila Pass, Binangonan and Masbate upper limestones. Following Martin[5] in his work on Java, and Newton and Holland[6] on Formosan fossils, I have been inclined to assign this formation, at least this horizon of it, to the Miocene, although fossils from a very similar limestone which I have also examined in the field in Batan Island have been classified by a European paleontologist[7] as Oligocene. The fossils so classified were collected by Mr. O. Halvorsen Reinholt and he simply states that they came from above the coal. However, I suspect, judging from similar forms which I collected myself on Batan Island, that his forms did not come from the uppermost horizon, therefore, future search and study of the fossils already collected may reveal this Oligocene horizon in Cebu.

It will be of interest to attempt to correlate our Cebu section with Verbeek's[8] classification of the Eocene in Java as amended in 1892, which is as follows:

Stage IV. Orbitoides—Miocene.
III. Marl sandstone—Oligocene.
II. Quartz-sandstone—Eocene.
I. Breccia stage—basal conglomerate.

This scheme is more in accord with Martin's idea as expressed in 1900, as follows:

Quaternary; consisting of fluviatile and marine deposits, the latter rich in Mollusca, and at some localities remains of whales.

Upper Pliocene; represented by the Rendon Beds, rich in remains of *Stegodon* and *Cervus*, containing also *Pithecanthropus erectus* Dub.

Pliocene-Miocene, or the Java series, possibly including some pre-Miocene rocks. This constitutes the greater part of the Island of Java and most of the fossils from the island which have been described come from it. Among them are

[5] Tertiärschichten auf Java, Leyden (1880).
[6] *J. Coll. Sci. Imp. Univ.*, Tokyo (1902), **17**, Art. 6.
[7] Reinholt, O. Halvorsen: *Engineering Journ.* (1906), **30**, 510.
[8] Neues Jahrb. fur Mineralogie, etc. (1892), 66.

PLATE III.

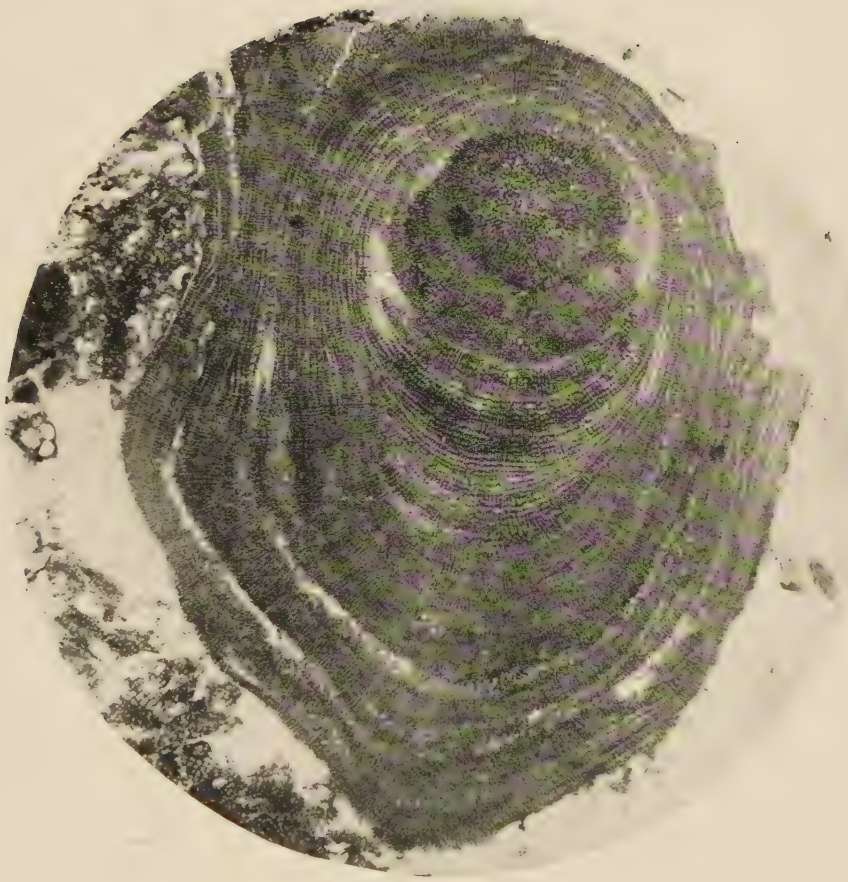

PLATE IV.

*Lepidocyclina* and *Cycloclypeus*. This series extends northward through the Philippines to central Japan.

Eocene; marine beds of small extent with *Nummulites*, *Alveolina* and *Orthophragmina*. They contain coal.

Cretaceous limestone with *Obitolina* from *Banjoemaas*. This rock is not known to exist at other points in Java.

By comparison with the table on page 390 it will be seen that my column is fairly well in accord with Verbeek's divisions in Java, and with Martin's Pliocene-Miocene or Java series.

*Recent formations.*—The latest deposits to be laid down in this region are those which are still forming in the river bottoms, on the coastal plains where the streams issue from the mountains, and along the coast, but in our limited field we need only refer to two of these, the river-bottom deposits and the talus slopes, for these are in part alluvial, although gravity is probably much the most potent agent in producing the latter, whereas water is the cause of the former.

All the waters in this region in addition to the mechanical detritus of the streams, carry a large quantity of lime in solution. This is generally deposited on the shales of the coal measures. I have picked up fresh-water snail shells which had a coating of half an inch in thickness of calcium carbonate.

## STRUCTURE.

The importance of geologic structure is nowhere exemplified as it is in a coal field. Not only the condition of the coal is generally greatly changed by an increase in the inclination of the strata, but the cost of mining is enhanced almost in geometric ratio under certain conditions; an instance of such conditions being those under which the miner is forced to work down the dip, hauling the coal up an incline by steam or electricity, and where it is necessary to pump. In discussing the structure of this district I shall merely make mention of the structure of the coal measures. The general strike of the formations on the east coast of Cebu is north and south, but in the Compostela-Danao region the *Cordillera* swings somewhat to the east and likewise the strike of the coal measures changes to about N. 25° E. The dip, which on this side is generally easterly, changes to southeast. It is not uniform, uninterrupted and always to the east, but in some places the formation is plicated to an extreme degree, with westerly dips. An instance of the close folding is shown in the cut of the tramroad just below the Camarin at Camansi, and again in Suqui Creek, where the igneous rock is approached; besides this there seems to be abundant indication of a minor north and south cross folding, but this is not a bad feature, as it is not noticeable except over great distances.

I am not able to assert that much indication of faulting appears on the surface, although I suspect it to have been considerable, but of a minor character, in this district and until more underground data are

acquired, I shall dispense with further discussion of this feature, merely stating that in the very limited workings of the Spaniards, several faults were encountered, but according to Abella, who examined them all, they were neither sufficiently great nor numerous to cause any serious difficulty in mining operations.

I shall now briefly summarize the geological history of this district, before passing on to the discussion of its economic phases. We may think of a basal mass of igneous rock with little or no sediments covering it. Whether this was a part of the mainland of a then extended continent, or an outlying island mass, we can not at present say. This igneous mass must have had some elevation, otherwise the later sediments could not have been formed. About this igneous mass a coral platform undoubtedly formed in places. This grew up to a limiting plane, the sea level. Upon this, the detritus of the hills poured and made a shelf. This substructure of coral may have been lacking in other parts. At all events, there were low, tidal flats, girting the elevated igneous mass at the beginning of the Eocene. These flats were the sites of unusually rank forests, and deposits began to form which afterwards were to become coal. Sinking of the whole mass must have begun at this time and later elevation again occurred. There were periods of quiescence, followed by oscillations of level, in which shales and coarse sandstone were alternately deposited above the coal beds. Finally, there came at the close of the Eocene a subsidence so great that the entire mass sank under the sea and a coral mantle was deposited over the whole region. At the close of the Miocene, which was the period of the deposition of the limestone, there occurred a period of uplift and rather pronounced folding of the strata. Since that time erosion has denuded the area of a large part of its mantle of limestone, uncovering the coal-bearing formations below.

## GEOLOGY: ECONOMIC.

### HISTORY OF THE DISTRICT.

As the complete history of the discovery of coal and operations in Cebu is recorded in "The Coal Measures of the Philippines"[9] which is simply a compilation and translation from the Spanish records, I will only in this place summarize what was given.

Coal was discovered in Cebu in 1827. The first concessions in the Compostela-Danao region were solicited by Isaac Conui in 1871. A wagon road was built from Cot-Cot cove to the workings at Dapdap in 1877. The formation of the association known as the *Sociedad Nuevo Langrea* and the beginning of actual work took place about 1890. The construction of a tramroad from Danao to Camansi, and from Compostela to Mount Licos, was undertaken in 1895. Then followed the Spanish-American war in 1898. In this year all the concessions in this district came into the hands of Mr. Enrique Spitz. These concessions have

[9] Burritt, Chas. H.: Wash. (1901).

changed hands again and are controlled by the Insular Coal Company, which is now in the field carrying on exploratory work.

*Operations.*—It will be sufficient at the present time to state that two companies, of which the Insular Coal Company is one and the other a New York syndicate, are vigorously investigating these fields; the Insular Coal Company in the Mount Licos and Camansi regions, the latter in the Cajumayjumayan Valley. As both these companies seem to be very much in earnest and backed by responsible men who command considerable capital, we should obtain as a result of their investigations a far more thorough knowledge of these fields than we now have.

The district is one in which the geology is very complicated but not more so, it is believed, than that of other coal-bearing areas of the Archipelago. It certainly has some features possessing advantages over other parts of the Island of Cebu, although coal may be found in almost all districts of the island.

### COAL SEAMS.

The three fields at present being developed are rather limited, but amply sufficient for a considerable production of coal. Various estimates have been made of the possible tonnage, some of which are founded on guesswork and are very wild. A very conservative estimate would be 2,000,000 workable tons in the Cajumayjumayan valley and two to four million in the combined Mount Licos and Camansi fields. The coal seams are rather highly inclined, from 30° to 90°, which would necessitate some system like the "Battery" being employed. The proper drainage of the workings will be a serious factor. Both the roof and floor are weak, the floor being of shale and fire clay, and the roof of shale or friable sandstone. Great care will need to be taken in timbering. There will also be increased expense for timber, because the greater part of it will need to be brought from some distance, probably from another island (see Forester Everett's timber report in the first part of this paper, p. 384). Methods for preservation of mine timbers must be devised. However, when molave is used the timbers will last for many years; in fact I have examined such timbers which were for nearly ten years completely buried in loose earth in the "Enrique Abella" tunnel and they were perfectly sound. It must be remembered that timber does not last underground proportionately as long in the tropics as in higher latitudes. Forepoling and lagging will be necessary in the shafting and drifts.

There is evidence of considerable minor faulting, but probably none which will seriously affect mining operations. There are five known coal seams, at least three of which should be profitable; two of these are over ten feet thick in one part of the field. The following beds were encountered at Mount Licos, from west to east, that is from lowest to highest:

1. The "Cármen;" thickness 1.60 meters, strike NE.–SW., dip 30° SE.; 40 meters interval.

2. "Esperanza;" 50 centimeters, strike the same as above, dip same; 9 meters interval.

3. "Enrique Abella;" thickness 1.20 to 1.50 meters, strike N. 23° E., dip 40° to SE.; 40 meters interval.

4. "Pilarica;" thickness 1.40 meters, strike N. 23° E., dip 30° SE.

There formerly existed over 300 meters of drifts at the old Licos workings. About 100 tons of coal, taken from the "Esperanza," "Ramoncita" and "Enrique Abella" galleries have been on the dump for three or four years. In this time the coal has not taken fire, nor has it "air-slacked" very greatly, which bodes good for its handling and storing. The coal throughout the district is remarkably free from dirt, "butter" and "bone" and is quite low in sulphur.

We believe that this coal will ultimately find its greatest utility as a gas producer and with this end in view it should be mentioned that Dr. Cox, of this Bureau, is devoting much of his time to experimenting on this problem. It is hoped that at no distant date the Bureau of Science will be able to make a practical demonstration in this direction. The Philippine Commission has just appropriated a sum sufficient to cover the expense of installing a producer gas plant at the laboratory of this Bureau.

Dr. A. J. Cox has added a contribution from his own chemical investigations. His report is as follows:

The quality of the coal from the Cebu fields is no exception to the general average of this commodity in the Philippines. I have been over a large part of the territory and have analyzed samples from all the sources where coal is known to occur. None of the samples show a woody structure, and in general the coal is compact, lustrous and commonly has both hackly and conchoidal fracture. The coal as mined is very black, but when finely powdered (60 mesh) it assumes a tinge of brown. It is of the non-coking, sub-bituminous to bituminous variety. The latter class is perhaps best represented by that from the Compostela region. In this field the active work which is now being carried on is beyond the prospecting stage, so that more definite information is at hand regarding the extent of the deposits and thoroughly average samples have been obtained for chemical work. A study of the volatile matter from this coal shows it to contain a fairly good percentage of heavy hydrocarbons and it could probably be used successfully as a gas coal. The composition of the gas and the yield from this coal is not greatly different from that obtained from Polillo[10] coal. Attention has already been directed to the peculiar, elliptical, pit-like markings which characterize Compostela coal.[11]

I have analyzed a great many samples from both the Carmen and Compostela fields. Some of the results have already been published[12] and other more recent determinations will be printed in a future communication. Barring diluents, water, ash, sulphur, etc., and considering the relation of the percentage of volatile combustible matter to fixed carbon, which by many authorities is taken

[10] Cox, A. J.: *This Journal* (1906), **1**, 893.
[11] *Ibid, Sec. "A," Gen. Sci.* (1907), **2**, 50.
[12] *Ibid*, 52.

as the criterion of classification, there is a surprising regularity in the analyses of all of the samples taken from a single field. The averages of all the samples give the following results:

*Averages of analyses of Cebu coals.*

[The figures give percentages.]

| Constituent. | For the Carmen region. | | | For the Compostela region. | | |
|---|---|---|---|---|---|---|
| | Minimum. | Maximum. | Average. | Minimum. | Maximum. | Average. |
| Moisture | 13.5 | 21.6 | 16.70 | 7.5 | 9.5 | 8.60 |
| Volatile combustible matter | 33 | 38 | 35.10 | 35.1 | 38 | 36.95 |
| Fixed carbon | 38.7 | 49.3 | 43.92 | 51.3 | 52.8 | 51.75 |
| Ash | 1 | 8 | 4.28 | 1 | 3.8 | 2.70 |
| Total | | | 100 | | | 100 |
| Sulphur | .1 | 2.7 | .67 | .2 | 1.3 | .71 |
| Calorific value in calories | 4,820 | 5,920 | 5,330 | | | 6,380 |

Although a careful study has been made of all of the Philippine coals thus far discovered, not a single sample of coking coal has been found. The usefulness of a coke in this Archipelago is well recognized, for were it to be readily accessible the iron industry would be in line for development. In view of this I have tried to make coke in various ways. The coal from the Compostela region yields a certain per cent of tar and it was thought that by mixing this product with the coal itself before charging into the coke oven, a good coke might result. Several experiments were made. The pulverized coal and tar in varying amounts up to 12 per cent of the weight of the coal were warmed to 110°, intimately mixed and then subjected to a heat similar to that of a coke oven; in fact, the heat was varied to cover the various ranges present in coke ovens. All experiments gave negative results. In none of them was there more than a semblance of coke, consequently for the present we must give up the hope of obtaining coke in these Islands.

I have added below a copy of an analysis of the upper limestone which will be of interest in view of the fact that possibly a cement plant will be erected in this region at some future date. As this paper has been devoted almost entirely to the question of the coal, I shall not discuss this matter further at the present time.

The absence of magnesia which seems to be characteristic of recent limestones, should be noted.

*Analysis of the limestone.*

| | Per cent. |
|---|---|
| Insoluble acid | 0.36 |
| $Fe_2O_3$ } $Al_2O_3$ } | .18 |
| CaO | 55.62 |
| Loss on ignition | 43.50 |
| $H_2O$ at 110° C. | .17 |
| Total | 99.83 |

### LABOR.

Labor conditions on the whole are good in Cebu, and in the Compostela-Danao district the natives have more or less familiarity with underground work, gained by experience of a score of years under the tutelage of the Spaniards. The present wage in this field is 40 centavos and subsistence, for the outside laborers, and 50 centavos for the underground man; however, of late the Insular Coal Company has found it best to pay so much a foot for driving a drift. The price per foot will of course vary according to conditions. The Philippine Railroad Construction Company has found the native labor to be very satisfactory. In their work thousands of natives are used at a wage of 50 centavos and subsistence. The subsistence is arranged for by contract with a Chinaman. It is the belief of many in these Islands that the Visayans are the best laborers of any of the tribal groups. However, this is a matter more or less of personal opinion.

### TRANSPORTATION.

The new railroad from the city of Cebu to Danao, a distance of 32 kilometers (20 miles), is completed at this date. From Danao to the Camansi workings is a distance of about 8 kilometers (5 miles) with a rise of 75 meters (250 feet). There is now a tramroad over this course, an heirloom from the Spanish régime; but this will need to be replaced by new rails and more clearing will have to be done before any extensive work is undertaken. The transportation problem in the other parts of the district will not be so simple and I believe overhead cables or inclined planes will be found to be necessary.

### RECOMMENDATIONS.

I would caution any company which intends any great outlay of money, thoroughly to explore the field with drills or by means of numerous drifts. I do not believe the diamond drill will be best for these soft formations, but a churn or a calyx drill should be on hand for certain parts of the work. The disadvantage in using such a drill is the difficulty found in obtaining an accurate record of the formations encountered. It would be foolish, judging from the folded condition of the rocks, to suppose that the beds will continue as they appear along the outcrops. Without more records from shafts, drifts or bore holes, I should consider any estimates as to the quantity of coal, the position of the beds and their condition to be little more than guesswork.

The vicinity of Luguayan Creek on the eastern edge of the map should be prospected, as here the coal is found exposed below the upper conglomerate. It is probable that in this position the beds are less folded than they are farther to the west. I should even go so far as to predict the finding of good, regular beds underlying the more level country near

Danao. The saving in transportation and the greater regularity of the beds might more than offset the cost of sinking a shaft and pumping.

I may also add that drilling in the vicinity of the andesite formation might, not improbably, discover anthracitized coal, should the andesite come in contact with the coal bed at any point. This has been known to be the case in the anthracite region of Colorado, in the United States.

In conclusion it should be said that the coal formation in this district does not differ greatly from that of Batan Island and operations in either field will necessitate considerable outlay of capital. Furthermore, the problem connected with coal mining in either field will tax the ingenuity of any engineer and it will be a saving in the long run to spare nothing in order to get the best man available.

# ILLUSTRATIONS.


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XIII. The upper limestone dipping to the east in a gorge of the Danao River.

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Map No. 1.

Map No. 2.

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PLATE VIII.

PLATE IX.

PLATE X.

PLATE XI.

PLATE XII.

PLATE XIII.

PLATE XIV.

# MAP OF

# COMPOSTELA-DANAO COAL MINING DISTRICTS

## CEBÚ P. I.

Scale : 1 inch = 000 ft.
Contour Interva 50 ft.


SURVEYED BY
MAURICE GOODMAN
HARRY M. ICLIS
FIELD ASSTS MINING DIVISION BUREAU OF SCIENCE



MANILA P. I.
MARCH - MAY 906


LEGEND

- Alluvial
- Upper hard limestone / Lower shaly "
- Andesite, tuffs and sediments derived from extrusive igneous rocks
- Conglomerate ss and shales largely terrestrial
- Coal Seams
- Coal Measures
- Basal Mass including conglomerate
- Unmapped

Mt. Lanhuan
Mt. Mangilao
Elevation 2245 ft.
Mt. Binaleu
Mt. Licos
Elevation 1789 ft
Clamp. Clark
Mt. Acsubing
Mt. Lanboga
Nauting Bato
Dunga Creek
Camajimayan Creek
Ogi Creek
Sibacan Creek
Sili Creek
Bucao River
Ustigahin River
Mananga River
Magiji River
Danao River
Isagudjan Creek
Tr. Bg. Danao Church S. 58° 25' 35" E. 23652 ft.
Tr. Bg. Compostela Church S. 20° 38' 10" E. 39163 ft.
Tr. Bg. Liloan Lighthouse S. 12° 50' 49" E. 64403 ft.
Tr. Bg. Compostela Church S. 30° 36' 15" E. 21757 ft.
Tr. Bg. Danao Church S. 30° 27' 40" E. 37762 ft.
Tr. Bg. Bantad
Tagnanan Cr.
Timaro River
Mudo River
Parel River
Antagan
Canagajan
Cadac-an
Bº Masaba
Bº Ballang
Bº Basan
Bº Mudo
Bº Panangban
Bº Cabadiangang
Bº Siglo XX
Bº Lalaban
Bº Candagit
Bº Tagbilid
Col. Col River
Profile and section along the road to the Compostela Mines ( after Abella )
In this portion of the section the road follows approximately the strike of the beds.
This portion runs north to south

# MINAS DE CARBÓN DE COMPOSTELA

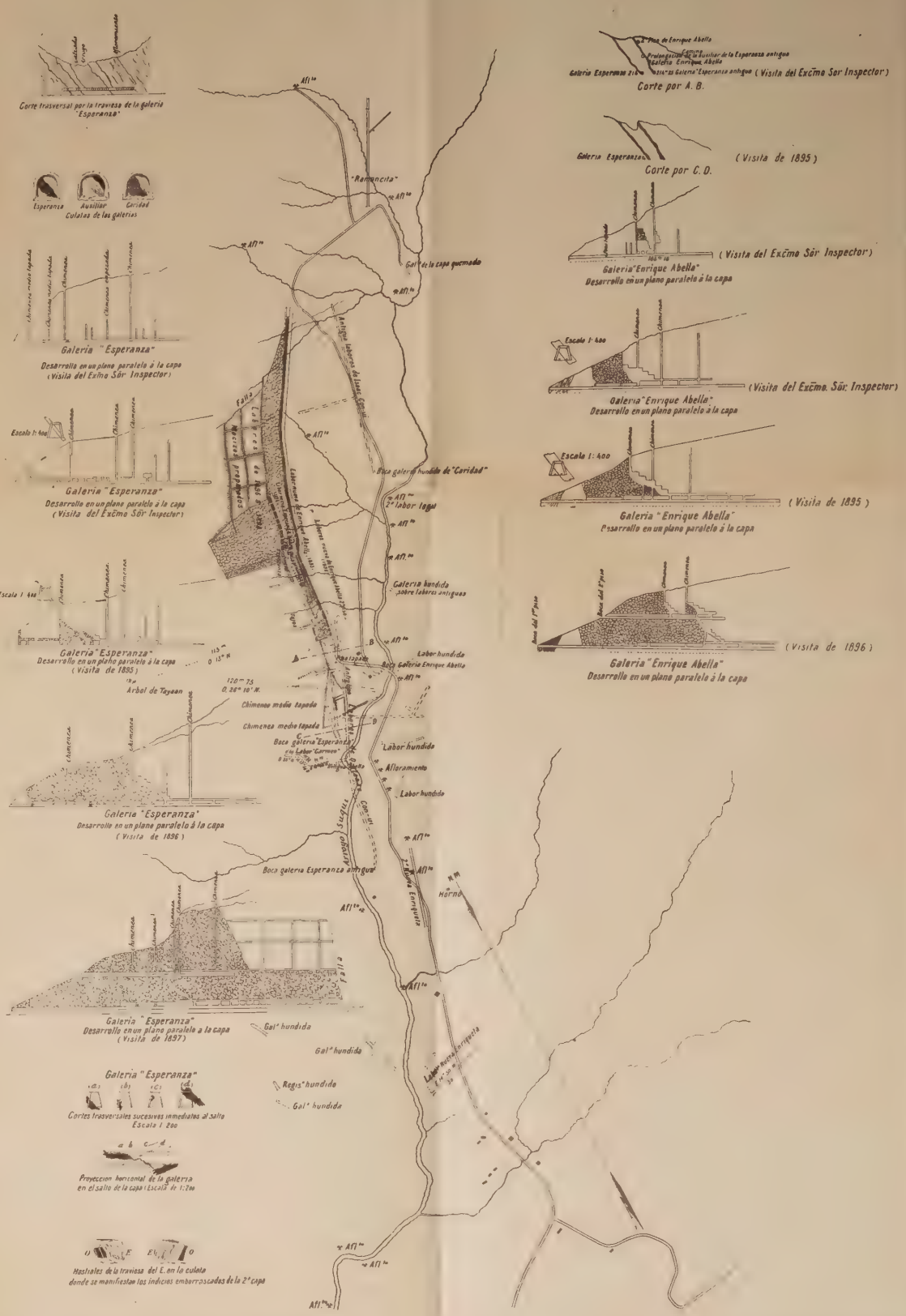
CEBÚ

# PLAN OF WORKINGS

1898

*(Permission of the Insular Coal Co)*

Scale 1: 2000


Corte trasversal por la traviesa de la galeria "Esperanza"
Esperanza
Auxiliar
Caridad
Culatas de las galerias
Galeria "Esperanza"
Desarrollo en un plano paralelo á la capa
(Visita del Excmo Sôr Inspector)
Galeria "Esperanza"
Desarrollo en un plano paralelo á la capa
(Visita del Excmo Sôr Inspector)
Galeria "Esperanza"
Desarrollo en un plano paralelo á la capa
(Visita de 1895)
Galeria "Esperanza"
Desarrollo en un plano paralelo á la capa
(Visita de 1896)
Galeria "Esperanza"
Desarrollo en un plano paralelo á la capa
(Visita de 1897)
Galeria "Esperanza"
Cortes trasversales sucesivos inmediatos al Salto
Escala 1 200
Proyeccion horizontal de la galeria en el salto de la capa (Escala de 1:2m)
Rastrales de la traviesa del E. en la culata donde se manifiestan los indicios embarrascados de la 2ª capa
"Ramoncita"
Gal.ª en la capa quemada
Antiguas labores de Jesus Comes
Falla
Labores antiguas de Enrique Abella
Boca galeria hundido de "Caridad"
2ª labor lagas
Galeria hundida sobre labores antiguas
Labor hundida
Boca Galeria Enrique Abella
Arbol de Tayaan
Chimenea media tapada
Chimenea mucho tapada
Boca galeria "Esperanza" en Labor "Carmen"
Labor hundida
Alleramiento
Labor hundida
Boca galeria Esperanza antigua
Labores Enriqueta
Horno
Gal.ª hundida
Gal.ª hundida
Regis.ª hundido
Gal.ª hundida
Labor hundida
Corte por A. B.
Galeria Esperanza
(Visita del Excmo Sôr Inspector)
Corte por C. D.
Galeria Esperanza
(Visita de 1895)
Galeria "Enrique Abella"
Desarrollo en un plano paralelo á la capa
(Visita del Excmo Sôr Inspector)
Escala 1: 400
Galeria "Enrique Abella"
Desarrollo en un plano paralelo á la capa
(Visita del Excmo. Sôr. Inspector)
Escala 1: 400
Galeria "Enrique Abella"
Desarrollo en un plano paralelo á la capa
(Visita de 1895)
Galeria "Enrique Abella"
Desarrollo en un plano paralelo á la capa
(Visita de 1896)

LIT. DE R. MONTES MAGALLANES 40 MANILA.

# NOTE ON THE OCCURRENCE OF RHYOLITE IN CEBU.

By Henry G. Ferguson.

*(From the Division of Mines, Bureau of Science, Manila, P. I.*

This rock, collected by Mr. Warren D. Smith during his investigation of the coal fields of Cebu,[1] seemed to be of interest because of the difficulty in determining whether it should be classed as an igneous rock or a siliceous precipitate.

The field relations are not at all clear. The rock occurs in scattered outcrops along the side of the Muao River valley, and near the Bureau of Science bench mark (B+S on the map accompanying Mr. Smith's paper). "Greenstone" and andesite outcrop in the stream bed, and limestone forms the capping of the hill. The contacts are everywhere masked by talus.

CEBU NO. 57.

*Hand specimen.*—The rock in the hand specimen is whitish, compact and extremely fine grained. It is rather light, four determinations of specific gravity giving: 2.20, 2.26, 2.10, 2.17, average, 2.18. It is sufficiently soft so that it can be scratched with a knife and gives no effervescence with hydrochloric acid. In one part of the specimen there is a well-marked banding which consists of small, slightly darker lines about 2 millimeters apart. A slight tendency to break along this banding was noticed in making the thin sections. A few small grains of magnetite appear in these dark bands. The rock is too fine grained for any other minerals to be identified in the hand specimen.

Another specimen bearing the same number seems to be a more weathered phase of this rock. The color is light green instead of white, as in the unaltered specimen. Beyond this the rocks seem the same. One grain of quartz (about 0.5 millimeter in diameter) was seen in the weathered rock. No banding was noticed. Specific gravity 2.14, 2.15, 2.15.

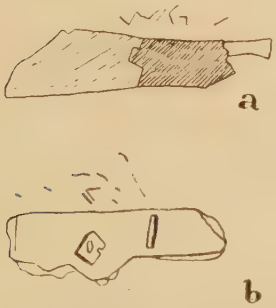



Fig. 1.—*a*, Broken quartz grain; *b*, quartz grain with inclusions.

*Microscopic.*—The most easily recognizable minerals are quartz and feldspar, occurring in minute grains. The quartz is clear and glassy, the grains as a rule have sharp edges; and apparently, in some cases at least, crystal faces are present. The grains sometimes are broken and occasionally contain inclusions.

The feldspars occur in small, clear, fresh grains. The edges are sharp, but there are no idiomorphic crystals. Only one good determination could be made and this gave basic oligoclase (extinction angle of albite twins, 6° and index of refraction lower than quartz). Probably the majority of the undetermined feldspars are orthoclase.

[1] Smith, W. D.: *This Journal, Sec. "A," Gen. Sci.* (1907), 2.

Rare grains of epidote occur, generally along the darker bands.

The groundmass in great part is composed of small rods and grains of a practically isotropic mineral with a slight greenish tinge, which, with crossed nicols, gives a very faint, grayish polarization or remains entirely dark. The index of refraction is lower than balsam, hence they are either crystallites or else small rods of opal. They have a wavy, parallel arrangement suggesting flow structure (microfelsitic). Between these rods are aggregates of a mineral having low polarization colors and suggesting chlorite. These sometimes have definite boundaries suggesting the replacement of some other mineral, or possibly only a large interspace between the small rods, or else they fill up irregular interstitial spaces. The polarization is extremely irregular and parts of these aggregates seem isotropic, hence they may represent a cryptocrystalline structure resulting from devitrification.

Small aggregates of a mineral having a high double refraction and resembling either sericite or talc also occur, but these are rare. The banding seems to be due to small patches of nearly opaque brownish matter.

Below is an analysis made by Mr. Herbert S. Walker of this Bureau.

*Analysis of Cebu No. 57.*

| | Per cent. |
|---|---|
| $SiO_2$ | 67.25 |
| $Al_2O_3$ | 13.12 |
| $Fe_2O_3$ | .24 |
| CaO | 1.23 |
| MgO | 1.10 |
| $K_2O$ | 4.38 |
| $Na_2O$ | 0.59 |
| $H_2O$ at 11° | 6.15 |
| $H_2O$ on ignition | 6.11 |
| Total | 100.17 |

The most striking features of the analysis are: (1) The rather large ratio of aluminia to silica, 1 : 5.1, which is above what would be expected in a siliceous precipitate; (2) the large percentage of both contained and included water, which would be natural to expect in a chemical precipitate of the nature of a novaculite, having an opaline groundmass, but which, if the rock is igneous, must be referred to devitrification and chloritization of the groundmass, a process which seems hardly far enough advanced to justify such a large amount of water; (3) the extremely low iron content, natural to a precipitate but hardly to be looked for in an igneous rock as fresh as this appears to be; (4) the comparatively high percentage of magnesia; (5) the great excess of potash over soda (7.4 : 1 taking percentage values, or 4.7 : 1 taking molecular proportions).

In addition to the high water content and the low percentage of iron, there are two other arguments against the rock being of igneous origin First, the specific gravity (2.18) is abnormally low for an igneous rock, but neglecting all the water this figure would increase to about 2.6, and

neglecting only the water lost at 110°, to about 2.4. Second, the quartz and feldspar do not occur in well-formed crystals, but in sharp, angular grains with the quartz often cracked, as if the siliceous waters forming the precipitate had carried a small amount of clastic material. However, fig. 1 and Plate I, fig. 1, show that reëntrants are common and the absence of crystal forms may be explained by magmatic corrosion.

The small isotropic rods may be either casts of, or precipitates around algæ,[2] or they may be crystallites formed in the glassy base of an igneous rock. They seem to bear a greater resemblance to the latter. The banding may be explained as either the result of original deposition or as a flow structure.

Below are tables of analyses of different rocks for comparison and a recast of the analysis of this rock and classification by the quantitative system. I have not been able to find any analysis of siliceous precipitates which at all corresponds to this rock, the nearest being a pulverent sinter, No. 9. It will be seen that the rock agrees closely with Nos. 2, 3, and 4 and falls into the same subrang in the quantitative system.

*Comparative table of analysis.*

| Constituent. | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. |
|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 76.51 | 76.41 | 72.68 | 74.58 | 75.20 | 73.91 | 99.47 | 81.95 | 94.63 |
| $Al_2O_3$ | 14.93 | 14.42 | 15.62 | 13.31 | 12.96 | 15.29 | .17 | 6.49 | |
| $Fe_2O_3$ | .27 | .48 | .95 | 1.31 | .37 | | | | 15.95 |
| FeO | | .74 | n.d. | n.d. | .27 | .89 | .12 | Trace. | |
| MgO | 1.24 | .24 | Trace. | .26 | .12 | | .50 | .15 | Trace. |
| CaO | 1.40 | 1.43 | .63 | 1.61 | .29 | .77 | .90 | .50 | 1.00 |
| $Na_2O$ | .67 | .63 | 1.17 | 1.52 | 2.02 | 3.62 | .15 | 2.56 | .30 |
| $K_2O$ | 4.98 | 3.88 | 4.30 | 4.87 | 8.38 | 4.79 | .07 | .65 | 1.02 |
| $H_2O$— | | 1.02 | 2.90 | 2.03 | [a].58 | 1.19 | .12 | 7.50 | 7.43 |
| $CO_2$ | | 1.40 | | | | | | | |
| Total | 100.00 | 100.65 | 100.02 | 99.49 | 100.19 | 100.46 | 101.50 | 99.80 | 99.97 |

[a] Loss.

Specific gravity, 2.229.

1. Cebu No. 57, neglecting $H_2O$.

2. Porphyry, Käserngrat, Windgälle Mountains, Switzerland. Schmidt C.: *Neu. Jahrb.* B. B. (1886), **4**, 432. (Washington, H. S.: *U. S. G. S., P. P.* **14**, 130.)

3. Rhyolite, Nagy-Mihaly, Hungary. Murokozy K.: *Földtani Közlöny* Budapest (1892), **22**, 54. (Washington, H. S.: *U. S. G. S., P. P.* **14**, 130.)

4. Porphyry, Arolo, Lago Maggiore, Piedmont. Ricciardi L.: *Att. Acad. Gioen.* (1885), **18**, 14. (Washington, H. S.: *U. S. G. S., P. P.* **14**, 132.)

Nos. 2, 3, 4: Persalane { Columbare, Alsbachase, Mihalose, Quarfelic, Domalkalic, Dopotassic.

5. Rhyolite, Silver Cliff, Colo. Cross: *Col. Sci. Soc.* (1887), 229. (Kemp, J. F.: Handb. of Rocks (1906), 28.)

[2] Weed, W. H.: *U. S. G. S., 9th An. Rep.* (1888), 667.

6. Rhyolite, McClelland Peak, Washoe Dist., Nev. Gooch, F. A.: *U. S. G. S.* (1885), Bull. **17.** (Kemp. J. F.: Handb. of Rocks (1906), 28.)

7. Novaculite, Rockport, Ark. Beachett, R. N., for Griswold, L. S.: Geol. Ark. (1890), **3,** 161. (Kemp, J. F.: Handb. of Rocks (1906), 89.)

8. Geyserite, Yellowstone Park. Weed, W. H.: *U. S. G. S., 9th An. Rep.* (1889), 670.

9. Pulverent Siliceous Sinter, Rotura, New Zealand. Weed, W. H.: *U. S. G. S., 9th An. Rep.* (1889), 670.

*Recast analysis of Cebu No. 57, considered as an igneous rock.*

| Constituent. | Per cent. | Molecular proportions. | Orthoclase. | Albite. | Anorthite. | Corundum. | Hematite. | MgO $SiO_2$. | Quartz. |
|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 76.51 | 1.275 | 0.318 | 0.066 | 0.050 | | | 0.031 | 0.810 |
| $Al_2O_3$ | 14.93 | .146 | .053 | .011 | .025 | 0.57 | | | |
| $Fe_2O_3$ | .27 | .002 | | | | | 0.002 | | |
| CaO | 1.40 | .025 | | | .025 | | | | |
| MgO | 1.24 | .031 | | | | | | .031 | |
| $K_2O$ | 4.98 | .053 | .053 | | | | | | |
| $Na_2O$ | .67 | .011 | | | .011 | | | | |
| | 100.00 | | | | | | | | |

| Constituent. | | Per cent. | | | |
|---|---|---|---|---|---|
| Quartz | | .810 | 48.60 | Q 48.60 | |
| Orthoclase | | .053 | 29.47 | | |
| Albite | | .011 | 5.76 | F 42.18 | Salic 96.59 |
| Anorthite | | .025 | 6.95 | | |
| Corundum | | .057 | 5.81 | C 5.81 | |
| MgO. $SiO_2$ | | .031 | 3.10 | P 3.10 | Femic 3.42 |
| Hematite | | .002 | .32 | H .32 | |
| | | | 100.01 | 100.01 | 100.01 |

Class I. Persalane
Subclass I. Persalone
Order 3. (Quarfelic) Columbare
Rang 2. (Domalkalic) Alsbachose
Subrang 2. (Dopotassic) Mihalose.

# ILLUSTRATION.

PLATE I, FIG. 1. Photomicrograph of Cebu, No. 57.

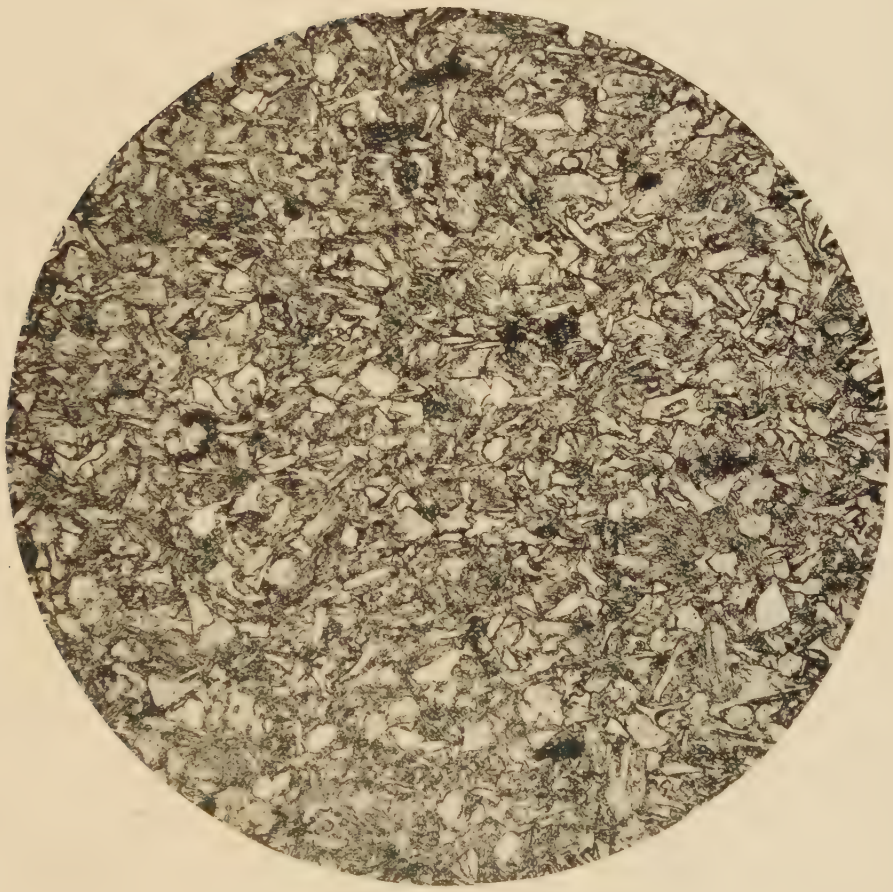


PLATE I.

# THE OCCURRENCE, COMPOSITION AND RADIOACTIVITY OF THE CLAYS FROM LUZON, PHILIPPINE ISLANDS.

By Alvin J. Cox.
(*From the Chemical Division, Bureau of Science, Manila, P. I.*)

## INTRODUCTION.

It seems hardly necessary to define a material of such common occurrence as clay, still at the outset a good definition may more clearly indicate some of its characteristics. Ries [1] says:

> The term clay is applied to a natural substance or rock which, when finely ground and mixed with water, forms a pasty, moldable mass that preserves its shape when air-dried and when burned, changes to a hard, rock-like substance by the coalescence of its particles through softening under the action of heat.

In other words, heat expels the volatile constituents, decomposes many of the finely ground particles and causes the clay to sinter together. Clays under the microscope are shown to be heterogeneous aggregates of hydrous and anhydrous aluminium silicates mixed with a variable quantity of other crystals, mineral particles and impurities in all stages of decay. The fact that silicate of aluminium is so characteristic a constituent of clay is caused by this substance being one of the most insoluble of natural compounds. The size of the crystals or particles varies from 0.01 millimeter up to grains distinctly visible to the naked eye. The varieties of clays are extremely numerous, as they form a continuous series ranging from pure kaolin (kaolinite) down to the more imperfect varieties. This variance is caused by the increasing admixture with kaolin of the common clays, consisting of other silicates of aluminium, the silicates, oxides, carbonates, etc., of iron, calcium, magnesium, and the alkalies, as well as free silica, and often organic matter. Kaolinite itself may only enter into this mixture in a small proportion. This variation is not surprising when we consider the difference in the composition of the original rocks from which the clays are derived. Kaolinite (pure kaolin) is derived from the aluminous minerals, especially feldspar.[2] In practice it rarely exists in the pure state, since decomposition

[1] *U. S. G. S., P. P.* (1903), 11, 15.

[2] Dana, J. D.: A System of Mineralogy, New York (1900), 319, gives 23 analyses of this species from varied sources. The average is as follows (figures give percentages): $SiO_2$, 65.06; $Al_2O_3$, 19.27; CaO, 0.68; $K_2O$, 10.85; $Na_2O$, 3.68; $Fe_2O_3$, 0.16; MgO, 0.07; BaO, 0.05; ignition, 0.08; total, 99.9.

of the pure, parent rock seldom takes place unassociated with that of other minerals, foreign substances in small amount being always mechanically mixed with it; however, because of its almost universal presence, it is often considered the basis of all clay. Kaolinite has the composition: $Si_2O_9Al_2H_4$;[3] or perhaps better $Al{<}^{OH}_{SiO_4\equiv H_3}{>}Al{-}SiO_4$ which indicates its relation to the parent mineral[4]; it contains alumina 39.45, silica 46.65, and water 13.9 per cent, respectively.

Other clays result not only from the decomposition of feldspar, but from the breaking down of other associated crystalline silicates to which they are related somewhat as kaolin is to the feldspars, and they also contain foreign matter which is mixed with them. Usually these mixtures are so complicated that it is almost impossible to identify them. Just as the clays range from pure kaolin to impure varieties, so in the end, because of a greater proportion of certain of the minerals in the parent rock, the products of decomposition may lose all the characteristic physical features of a clay and thus pass out of this class of bodies entirely.

Clay deposits are usually designated as residuary or sedimentary. As the names imply, these originate from their method of formation, accordingly as this is due to the decomposition of rocks in place or to the resulting decomposition products being transported by the streams and deposited in regular sedimentary beds elsewhere. Kaolin is termed a primary or residuary clay because it is always in the condition of original deposit. This is true of that from Laguna; that is, it is in place but thoroughly leached out. The formation of all clay begins in the same way, by the decay and disintegration of the rock mass. In this Archipelago, where we have no frost during the year, the principal active agents accomplishing this change are water and the sun. Dana[5] says, "Feldspar may be altered through the action of waters rendered acid by the decomposition of sulphides." Such waters filter into the rock, causing partial disintegration, then the drying action of the sun opens cracks for more water to enter and further to attack and break down the mineral grains in the rocks. By means of such infiltrating waters the feldspar of the feldspathic rocks acted on, first loses its lime, which is soon deposited as gypsum (calcium sulphate), next its alkalies as sulphates, and the change finally ends in kaolin or some other silicate of aluminium. In the less resistant portion of the vein the weathering will penetrate to a much greater depth than in the harder parts. An ideal section showing

[3] Groth, P.: Tabellarische Übersicht der Mineralien, Braunschweig (1898), 137.

[4] Clarke, F. W.: *U. S. G. S. Bull.* (1905), **125**, 28; McNeil, H. C.: *Journ. Am. Chem. Soc.* (1906), **28**, 592.

[5] System of Mineralogy, New York (1900), 320.

the characteristic breaking down in the formation of residuary clay deposits is as follows:

FIG. 1.

One of the best examples known to me where such decomposition is now going on is in northern Rizal along Macoburobod Creek. This stream empties into Poray Creek, San Mateo River, about 10 kilometers above Montalban. Its waters are extremely acid from the decomposition of sulphides. Along its banks is an outcrop of vein material carrying quartz which is characteristically weathered into clay and which shows the whole process taking place in the formation of primary clay deposits. The quartz is unaffected by the action of these waters and remains as grit in the final product. Wherever we have grit in a clay, we can almost invariably attribute it to unweathered particles of quartz which were present in the parent rock. An emulsion of the above clay was filtered through a sixty-mesh sieve. This filtrate, when thoroughly air-dried represents the result of the decomposition in this vein and the product is as follows:

| Constituent. | Per cent. |
|---|---|
| Silica | 59.00 |
| Alumina including titanium oxide | 16.79 |
| Ferric oxide | 7.87 |
| Ferrous oxide | 0.42 |
| Lime | 0.40 |
| Magnesia | 0.00 |
| Alkalies | 3.89 |
| Loss on ignition | 7.46 |
| Water below 110° | 3.18 |
| Sulphur | 4.79 |
| | 101.80 |
| Less oxygen | 1.79 |
| Total | 100.01 |

The formation of a great many of the clay deposits in various parts of the world is attributed to causes almost identical with the above. Bacon,[6] in connection with his investigation of the acid waters of "The

[6] *This Journal, Sec. A, Gen. Sci.* (1907), **2**, 120.

Crater Lakes of Taal Volcano" has recorded that aluminium hydrate is continually being deposited as a sediment from these lakes. It appears probable that many of the clay beds of the Philippines may have been deposited as a result of the chemical action of similar waters.

As the raw materials vary, so in a similar way do the uses to which clays are put, namely, the manufacture of porcelain, stoneware, earthenware, tiles (drain and roof), terra cotta, sewer pipes, common bricks, "vitrified" bricks for paving, doorknobs, playing marbles, as a filler for paper,[7] a food adulterant, etc. At one end of a series we find the analyses of the fine European porcelain, which is made from practically pure kaolin with admixtures of flint, feldspar, etc., and at or near the other we encounter the crude pottery of the majority of savage tribes, which is usually made from clay very high in iron and containing very little kaolin. If we continue in the direction of silicious dilution, we find the analyses of fire-clay wares and of the so-called "dinas brick" much used for building purposes in many places, for example in western Germany. The latter are pure, crushed quartz, excepting the residue from the milk of lime or clay in the water used for moistening the material before it is molded into the bricks and which is the cementing constituent.

## EXPERIMENTAL.

The object of this paper is rather to show in a preliminary way the geologic distribution and quality of clays on Luzon than to pronounce upon their economic values. The chemical composition is the first step toward a complete knowledge of the quality of these materials and I therefore give, in the following table, analyses and tests of a few specimens of the Luzon clays:

Sample No. DESCRIPTION OF THE CLAYS.

1. Kaolinite calculated from the theoretical formula $Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$.
2. Koalin or china clay from Los Baños, Laguna. Approaches closely to koalinite in composition.
3. Kaolin or china clay from the Vicenti Jesus mine, Laguna. Approaches closely to kaolinite in composition.
4. Kaolin or china clay, not from Luzon, but from Romblon. It approaches closely to kaolinite in composition and is given for the purpose of comparison.
5. Koalin or china clay from Laguna Province.
6. Kaolin or china clay from Los Baños, Laguna Province. Approaches closely to kaolinite in composition.

[7] Attention has already been directed by Richmond (*This Journal, Sec. A, Gen. Sci.* (1907), **2**, 81) to the probable usefulness of Philippine clays as a filler and a glazing material for paper manufacture. Standards for the purchasing and testing of such filling materials are given by Schacht, W., *Papier Ztg.* (1906), **31**, 4234; *Chem. Abstracts* (1907), **1**, 485.

7. Kaolin or china clay from the west side of Pajo Arroyo, Laguna Province. Approaches closely to kaolinite in composition. Taken from the bottom of a pit 3 meters deep.
8. Kaolin or china clay from Tagonton-Paracale, Camarines. Taken from the wall next to the vein in the San Mauricio mine.
9. Kaolin or china clay from Bauan Solfatara near Point Cazador, Batangas Province.
10. Kaolin or china clay from the east side of Pajo Arroyo, Laguna Province. Taken from the bottom of a pit 3 meters deep.
11. Kaolin or china clay from Bucay, Abra.
12. Kaolin or china clay from Calamba, Laguna Province.
13. Kaolin or china clay from Nasugbu, Batangas Province.
14. Kaolin or china clay from Albay Province.
15. Kaolin or china clay from Ilocos Norte.
16. Kaolin or china clay from Ilocos Norte.
17. Kaolin or china clay from Matiquo, Laguna Province.
18.[a] Kaolin or china clay from Dolores, Abra. Not quite white.
19.[b] Kaolin from Wolfson mine, Laguna Province.
20. Kaolin from the district east of Nasugbu, Batangas Province.
21. Silicious ferruginous kaolin. Exact source unknown.
22. Silicious ferruginous kaolin. Exact source unknown.
23. Kaolin from near Cervantes, Lepanto-Bontoc.
24. White, silicious clay from San Agustin-Magalang, Pampanga Province.
25. Dark, cream river clay from Laguna Province.
26. Gray river clay from Laguna Province.
27. Gray river clay from Laguna Province.
28. Gray river clay from Laguna Province.
29. Gray clay from Clarke's gold mine, Antimok, Benguet. This was refined by making an emulsion, passing through a 60-mesh sieve, and drying at 110° before analyzing. About 39 per cent of quartz and rock fragments were retained on the sieve and discarded.
30. Clay taken from the surface of a deposit of considerable extent which occurs on the banks of the Tinajeros River near Malinta, Bulacan Province. Clay of this quality seems to abound along the route of the Manila and Dagupan Railroad north of Caloocan.
31. Brick clay from Bulacan Province.
32. Common clay from Binangonan, Rizal Province.
33. Clay used in Mandaloyan on the Pasig River, for making brick. Taken from the bottom of a pit about 2 meters deep.
34. Clay from the first hills on the road to Bannangar, Rancherio Tablan, Benguet.
35. Clay used to paint houses. Near Nasugbu, Batangas Province.
36. Clay subsoil.
37. Igorot clay.
38. Igorot clay.

[a] It may be possible to remove enough iron by washing to make this clay available as an alkaline silicious kaolin. Otherwise it is of low value because the quantity of iron oxide is great enough to give a red body after firing, it is too alkaline for refractory ware and calcareous enough to have a low fusion point.

[b] It may be possible to remove iron from this by selecting and washing and to make it available as a first-class china clay.

TABLE I.—*Analyses of Luzon clays.*

[Figures give percentages.]

| Sample No. | Silica ($SiO_2$). | Alumina ($Al_2O_3$). | Fluxes. | | | | | | Loss on ignition. | Water ($H_2O$) above 110°.[a] | Water ($H_2O$) below 110°.[b] | Carbon dioxide ($CO_2$). | Titanic oxide ($TiO_2$). | Phosphoric anhydride ($P_2O_5$). | Sulphuric anhydride ($SO_3$). | Manganous oxide (MnO). | Total. | Total fluxes. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Ferric oxide ($Fe_2O_3$). | Ferrous oxide (FeO). | Lime (CaO). | Magnesia (MgO). | Soda ($Na_2O$). | Potash ($K_2O$). | | | | | | | | | | |
| 1 | 46.65 | 39.45 | | | | | | | 13.90 | | | | | | | | | 0.00 |
| 2 | 44.15 | 36.54 | 1.04 | | 0.15 | 0.00 | 0.98 | | 13.50 | | 2.64 | 0.00 | 1.14 | 0.00 | 0.00 | 0.00 | 100.14 | 2.17 |
| 3 | 43.32 | [c]41.48 | 0.32 | | 0.40 | 0.59 | 0.38 | | 14.12 | | 0.00 | | | | | | 100.61 | 1.69 |
| 4 | 47.76 | [c]37.04 | 0.75 | | 0.06 | 0.14 | 0.52 | | 13.73 | | 0.63 | 0.00 | | | | | 100.63 | 1.47 |
| 5 | 42.06 | 32.04 | 0.33 | | 0.48 | 0.32 | 1.77 | | [d]20.42 | | 2.08 | | 1.10 | | | 0.00 | 100.60 | 2.90 |
| 6 | 45.24 | 37.31 | 1.00 | | 0.66 | 0.00 | 1.69 | | 12.67 | | 1.24 | 0.00 | 0.98 | 0.00 | 0.00 | 0.00 | 100.79 | 3.35 |
| 7 | 44.30 | 37.28 | 0.83 | 0.64 | 0.39 | 0.42 | 0.49 | 0.51 | 12.56 | | 1.60 | 0.00 | 1.36 | 0.00 | 0.00 | 0.00 | 100.32 | 3.28 |
| 8 | 48.28 | 34.65 | 0.92 | | 0.00 | 0.59 | 0.40 | 2.90 | 10.34 | | 2.10 | 0.00 | 0.30 | 0.00 | 0.00 | | 100.48 | 4.81 |
| 9 | 30.30 | 30.37 | 0.57 | | 0.00 | 0.08 | 3.06 | 3.02 | [d]31.26 | | 0.80 | 0.00 | 0.68 | Trace. | 0.00 | | 100.14 | 6.73 |
| 10 | 57.68 | 26.54 | 0.99 | 0.05 | 0.56 | 0.17 | 0.54 | 0.40 | 10.74 | | 1.87 | 0.00 | 1.22 | 0.00 | 0.00 | | 100.76 | 2.71 |
| 11 | 64.57 | 23.23 | 0.84 | | 0.00 | 0.14 | 0.46 | 0.00 | 8.45 | | 2.73 | 0.00 | 0.38 | 0.00 | 0.00 | | 100.80 | 1.44 |
| 12 | 61.98 | [c]26.22 | 0.12 | | 0.60 | 0.72 | 0.34 | | 10.55 | | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | 100.53 | 1.78 |
| 13 | 62.74 | 23.85 | 1.60 | | 0.15 | 0.00 | 1.05 | 1.56 | 8.84 | | 0.00 | 0.00 | 0.78 | 0.00 | 0.00 | 0.00 | 100.57 | 4.36 |
| 14 | 71.16 | 16.94 | 0.48 | | 0.57 | 0.23 | 0.46 | 5.64 | 3.22 | | 1.56 | 0.00 | 0.58 | 0.00 | 0.00 | 0.00 | 100.84 | 7.38 |
| 15 | 62.26 | 18.56 | 0.91 | | 2.97 | 0.90 | 1.20 | 2.16 | 3.87 | | 7.29 | 0.00 | 0.48 | 0.00 | 0.00 | 0.00 | 100.60 | 8.14 |
| 16 | 65.75 | 16.40 | 1.24 | | 2.55 | 0.18 | 1.36 | 3.65 | 3.93 | | 4.26 | 0.00 | 0.52 | | | 0.00 | 99.84 | 8.98 |
| 17 | 62.94 | [c]22.08 | 1.36 | 0.20 | 0.47 | 0.77 | 0.67 | 4.84 | 5.42 | | 1.80 | 0.00 | | | | | 100.55 | 8.31 |
| 18 | 64.22 | 15.39 | 2.52 | | 2.42 | 1.52 | 2.32 | 2.10 | 5.43 | | 4.39 | 0.00 | 0.24 | 0.00 | 0.00 | | 100.55 | 10.88 |
| 19 | 49.95 | [c]31.84 | 3.96 | | 0.36 | 0.70 | 0.64 | | 11.90 | | 0.00 | 0.00 | | | | | 99.35 | 5.66 |
| 20 | 65.18 | 19.07 | 3.93 | | 0.00 | 0.28 | 0.56 | 0.50 | 9.04 | | 1.10 | 0.00 | 0.70 | 0.06 | 0.00 | | 100.36 | 5.27 |
| 21 | 69.08 | 21.57 | 2.64 | 4.10 | Trace. | 0.04 | 0.46 | 2.63 | 0.00 | | 0.00 | Trace. | | | | | 100.52 | 7.24 |
| 22 | 74.50 | 15.17 | 2.61 | 2.92 | Trace. | Trace. | 0.53 | 2.43 | 0.00 | | 0.00 | Trace. | | | | 1.79 | 99.95 | 6.06 |
| 23 | 53.63 | 24.30 | 5.88 | | 0.31 | 0.34 | 0.74 | 0.98 | 9.04 | | 4.48 | 0.00 | 0.74 | 0.00 | 0.00 | | 100.44 | 8.25 |
| 24 | 67.58 | 14.20 | 3.00 | | 2.30 | 0.27 | 2.24 | 2.88 | 4.60 | | 2.14 | Trace. | 0.30 | 0.00 | 0.00 | | 99.51 | 10.69 |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 25 | 59.46 | [c]28.00 | 0.16 | 1.04 | 1.29 | 1.41 | | 7.92 | | 0.00 | 0.00 | | | | 99.28 | 3.90 |
| 26 | 50.00 | [c]25.94 | 8.08 | 1.16 | 0.65 | 4.60 | | 8.64 | | 0.00 | 0.00 | | | | 99.07 | 14.49 |
| 27 | 52.72 | [c]26.86 | 4.10 | 2.04 | 2.03 | 2.57 | | 9.35 | | 0.00 | 0.00 | | | | 99.67 | 11.54 |
| 28 | 52.06 | [c]30.02 | 3.18 | 0.72 | 2.04 | 2.78 | | 8.58 | | 0.00 | 0.00 | | | | 99.38 | 8.72 |
| 29 | 47.22 | [c]25.73 | 9.70 | 0.60 | 4.30 | 0.95 | 3.24 | 10.23 | | 0.00 | 0.00 | | | | 101.97 | 18.79 |
| 30 | 47.77 | [c]18.73 | 7.19 | 1.78 | 2.06 | 1.86 | | 13.84 | | 8.42 | 0.00 | | | | 101.44 | 13.04 |
| 31 | 60.24 | 20.05 | 4.15 | 0.47 | 0.05 | 3.18 | 1.44 | 11.27 | | 0.00 | 0.00 | Trace. | | Trace. | 100.85 | 9.29 |
| 32 | 50.81 | 20.54 | 7.37 | 0.91 | 1.05 | | | 8.14 | | 9.98 | 0.00 | 1.18 | 0.00 | 0.01 | 99.99 | 9.33 |
| 33 | 52.53 | [c]21.01 | 8.40 | 4.04 | 2.58 | 2.68 | | 9.08 | | 0.00 | 0.00 | | | | 100.32 | 17.70 |
| 34 | 53.70 | 26.03 | 6.53 | 0.00 | 0.00 | 2.20 | | 8.95 | | 2.54 | 0.00 | 0.30 | 0.00 | 0.00 | 100.25 | 8.73 |
| 35 | 57.45 | 18.08 | 8.40 | 1.44 | 0.00 | 1.42 | | 8.56 | | 6.08 | 0.00 | 0.58 | Trace. | 0.00 | 101.99 | 11.26 |
| 36 | 49.68 | 18.34 | 1.70 | 0.46 | 0.28 | 0.00 | 0.06 | 14.46 | | 4.95 | 0.00 | 0.76 | | 0.00 | 100.96 | 2.50 |
| 37 | 54.46 | [c]16.77 | 11.14 | 0.53 | Trace. | Trace. | Trace. | 16.81 | | 0.00 | 0.00 | | | | 99.69 | 11.67 |
| 38 | 60.99 | [c]17.71 | 9.53 | 0.59 | Trace. | Trace. | Trace. | 10.65 | | 0.00 | 0.00 | | | | 99.47 | 10.12 |

[a] Included under loss on ignition which consisted mainly of this factor.
[b] Those samples where the factor is given as zero were dried at 110° before being analyzed. Others were taken as received or were only air-dried.
[c] Includes titanic oxide ($TiO_2$).
[d] The proportion of water seems abnormal.

In most places, the supply of clay for commercial uses is obtained from surface openings or clay banks and, with the exception of Numbers 8 and 29, this is the case with the specimens given in Table I. Some companies are operating underground works and so obtain a more uniform and purer product.

It is exceptional for clays to be used in their natural state for other than common work, because of the numerous bits of rock which are mingled with their mass. In almost every parent rock there are very hard mineral particles which resist the weathering and remain behind, contaminating the clay. A certain amount of sorting is always necessary. Herein is the justification for printing analyses of the unpurified specimens. It will at once be evident that the deposits will not through sorting become poorer than the published results. For the above reason, a chemical analysis of a residuary clay may not always be reliable as a means of judging its usefulness from the standpoint of the ceramic industries, as it may contain impurities which render it useless in the rough state, but by grinding and decantation it may be separated from its impurities. Ries [8] in summing up the facts obtainable from the ultimate analysis of a clay, gives the following main points:

1. The purity of the clay, showing the proportions of silica, alumina, combined water, and fluxing impurities. High-grade clays show a percentage of silica, alumina and water, approaching quite closely to those of kaolinite.

2. The refractoriness of the clay for, other things being equal, the greater the total sum of fluxing impurities, the more fusible the clay.

3. The color to which the clay burns. This may be judged approximately, for clays with several per cent or more of ferric oxide will burn red, provided the iron is evenly and finely distributed in the clay, and there is no excess of lime. The above conditions will be affected by a reducing atmosphere in burning, or the presence of sulphur in the fire gases.

4. The quantity of water. Clays with a large amount of chemically combined water sometimes exhibit a tendency to crack in burning, and may also show high shrinkage. If kaolinite is the only mineral present containing chemically combined water, the percentage of the latter will be approximately one-third that of the percentage of alumina, but if the clay contains much limonite or hydrous silica the percentage of chemically combined water may be much higher.

5. Excess of silica. A large excess of silica indicates a sandy clay, and if much is present in the analysis of a fire clay, it indicates low refractoriness.

6. The quantity of organic matter. If this is determined separately and it is present to the extent of several per cent, it will require slow burning if the clay is dense.

7. The presence of several per cent of both lime (CaO) and carbon dioxide ($CO_2$) in the clay indicates that it is quite calcareous.

Several of the above analyses do not to any large degree indicate accidental impurities. A few show minute traces of sulphuric anhydride, probably accounted for by crystals of gypsum which probably could be removed by washing. The iron in most cases is in all likelihood present

[8] Wis. Geol. and Nat. Hist. Sur. (1906), **15**, Econ. Ser. **10**, 12.

as the oxide resulting from the decomposition of iron sulphides during the original leaching of the clay material. In rough work it does little harm, and in fine work, if present in particles of any size, it could easily be removed by washing. In some of the Philippine kaolins the iron was observed to be in tiny grains. However, there are many things which are not shown by a chemical analysis. The results of such an analysis are expressed as if all of the metals existed as oxides and the acids as anhydrides. For example, gypsum ($CaSO_4$), calcium carbonate ($CaCO_3$) and siderite ($FeCO_3$) would be considered as present in the form of lime (CaO) and sulphuric anhydride ($SO_3$), lime and carbonic anhydride or carbon dioxide ($CO_2$), and ferrous oxide (FeO) and carbon dioxide, respectively. In general, the fusibility of a clay increases directly in proportion to the percentage of fluxing materials which it contains, but there are exceptions depending on the mineral condition of the oxides. If the oxide is present as a carbonate it generally fuses at a different temperature than if it were present in the form of a silicate, and furthermore, the fusibility of the various silicates of the same oxide components vary.

Some of the commonest minerals in clays are quartz, feldspar, calcite, dolomite, gypsum, apatite, pyrite, other iron ores, mica, talc, serpentine, hornblende, pyroxene, garnet, tourmaline, etc.; these are constituents of the parent rock which have escaped decomposition. With the exception of quartz, the particles are usually too small to be detected by the naked eye so that the "rational analysis" [9] and the mechanical analysis, to supplement the ultimate analysis, are resorted to in order to determine the different percentages of the minerals present. It is not claimed that these are accurate methods, but they are the best yet offered. When a great many different kinds of mineral particles are present in one clay, the methods become extremely complicated and with the common clays are seldom used. For kaolin, where the only constituents are kaolinite, feldspar, and quartz, the "rational analysis" becomes quite simple and especially useful and as most clay workers understand the relative importance of these constituents, when they are determined the behavior of the clay can approximately be estimated.

Research in the direction of mechanical analysis has established methods by which not merely the size of the grains, but also their shape, the specific gravity of the materials, etc., may be determined; these are important factors in establishing the usefulness of clays.

The determination of the fineness of the mechanical division is important, since it gives an idea of the loss when the material is prepared for certain kinds of work. The following data by Mr. L. A. Salinger show the proportion of certain sizes of grains in some of the clays

[9] The actual method is given in almost any text on clay analysis, for example: Ashby, H. M.: "How to Analyse Clay," Chicago (1901), 48.

mentioned in this paper. The raw clays were suspended in water, pressed through a 60-mesh sieve, and dried at 110°.

| Number. | Passed through 60 mesh (per cent). | Retained on 60 mesh (per cent). |
|---|---|---|
| 3 | 90.2 | 9.8 |
| 12 | 87.4 | 12.6 |
| 19 | 95.6 | 4.4 |
| 25 | 72.2 | 27.8 |
| 26 | 83.2 | 16.8 |
| 27 | 72.5 | 27.5 |
| 28 | 67.0 | 33.0 |

I have not been able further to study these properties at this time.

Bourry[10] has formulated a very satisfactory classification of clays, and he gives the following as a differentiation of the principal kinds of kaolin:

I. *Pure kaolins* do not contain more than from 5 to 6 per cent of silica and 2 per cent of fluxes, the proportion of each of the fluxes taken singly being not more than 1 per cent. They are always brought to this degree of purity by washing, and present themselves in the form of a white powder, occasionally slightly tinted with yellow, gray or red, and very unctuous to the touch. After firing they form a body of milky whiteness. They are used in the manufacture of porcelain and fine faïence.

II. *Alkaline kaolins.*—The only difference between these kaolins and the preceding is that they contain a higher proportion of alkalies, which can mount up to 5 per cent, coming from the mixture of feldspar and mica. In the meantime the proportion of oxide of iron rises sometimes to 2 per cent. They have the same use as the preceding, but it must be observed that a very careful washing results in taking away the greatest part of the alkalies.

III. *Silicious kaolins.*—In these kaolins, hydrosilicate of alumina is mixed in a considerable proportion with quartz in the state of impalpable powder. This content of silica depends greatly on the care bestowed in the washing; it can rise to 20 or 25 per cent. These kaolins furnish a body of small plasticity, and are of a light, granulous texture. They are used in the manufacture of porcelain and certain kinds of faïence, but for bodies which have no need to be very plastic.

IV. *Alkaline silicious kaolins* contain at the same time a considerable proportion of alkalies and of silica, and partake of the properties and uses of the two preceding kinds.

V. *Ferruginous kaolins.*—These kaolins contain a quantity of oxide of iron which is too great to give an entirely white body after firing. When this content is not too high it is utilized in the manufacture of porcelain and faïence of inferior quality. For a greater proportion[11] they can be used in the manufacture of refractory productions, but on the condition that they have not too much alkali.

The clays, the analyses of which are given above, have not been subjected to washing. Such treatment would probably improve and change the classification of some of them. As they are, numbers 1, 2, 3, 4, 5,

[10] Treatise on Ceramic Industries, London (1901), 59.

[11] Too much iron must be avoided, for it is a fluxing impurity and will lower the fusing point of the clay, especially when in the ferrous condition or in the presence of silicates. Fire clays should not greatly exceed 3 per cent of iron. If the clay contains 5 per cent or more it is suitable only for bricks.

6, and 7 would be classed as pure kaolins; 8 and 9 as alkaline; 10, 11 and 12 as silicious; 13, 14, 15, 16, 17 and 18 as alkaline silicious; and 19, 20, 21, 22 and 23 as ferruginous kaolins.

A satisfactory classification of common clays is more difficult and of less importance; therefore we will group all the remainder, namely numbers 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36 and 37 under this class.

Analyses numbers 1, 2, 3, 4, 5, 6 and 7 compare favorably with the analyses of the best quality of kaolin from all parts of the world which are given below:

TABLE II.[12]- *Analyses of the best quality of kaolin from all parts of the world.*

| Source. | Silica. | Alumina. | Ferric oxide. | Lime. | Magnesia. | Alkalies. | Ignition. |
|---|---|---|---|---|---|---|---|
| England | 47.10 | 37.33 | 1.11 | 0.14 | 0.47 | 0.20 | 13.45 |
| Do | 43.32 | 39.74 | 0.27 | 0.36 | ---------- | ---------- | 12.67 |
| Do | 45.52 | 40.76 | ---------- | 2.17 | Trace. | 1.90 | 9.61 |
| America | 47.66 | 37.56 | 1.39 | 0.20 | 0.36 | 0.25 | 13.47 |
| Do | 46.47 | 38.82 | 0.89 | 0.28 | 0.25 | 0.48 | 13.34 |
| France | 48.00 | 36.00 | ---------- | ---------- | ---------- | 2.00 | 13.00 |
| China | 50.50 | 33.70 | ---------- | ---------- | ---------- | 1.90 | 11.20 |
| Japan (Schiraye) | 47.74 | 36.68 | 0.42 | 0.99 | 0.30 | 0.45 | 13.64 |
| Germany (Dölau) | 48.15 | 37.03 | 0.60 | 0.27 | 0.30 | 0.82 | 12.76 |
| Bohemia (Zettlitz) | 45.68 | 38.54 | 0.90 | 0.08 | 0.38 | 0.66 | 13.00 |

The analyses of porcelains from China, Vienna, Meissen, Berlin, Sevres, etc., show a composition of—

| Constituent. | Minimum (per cent). | Maximum (per cent). | Average (per cent). |
|---|---|---|---|
| Silica | 53 | 75 | 66 |
| Alumina | 18 | 35 | 28 |
| Iron | As little as possible | | 0.8 |
| Lime | 0 | 5 | 1 |
| Magnesia | 0 | 1.5 | 0.2 |
| Potash | 0 | 5 | 2.5 } =4.0 |
| Soda | 0 | 3 | 1.5 } |

The water from kaolin passes off at a temperature somewhat above 330° (Hillebrand). If we recalculate the analyses numbered 1, 2, 3, 4, 5, 6 and 7 of Table I to the anhydrous clays as is shown by Table III, we have an average of fluxing materials much below that in the finished product given above. The alumina is higher and the silica lower, and this condition, as no flint has been added, is to be expected. The proper percentages of alumina and silica would be produced by the addition of the latter, and the fluxes would be reduced still lower, or a greater margin for impurities in the flint would be obtained.

[12] Binns, C. F.: Ceramic Technology, Lond. (1897), 11; Bourry: Loc. cit., 65.

TABLE III.—*Analyses of clays 1 to 7 recalculated to the anhydrous conditions.*

| Sample No. | Silica. | Alumina. | Ferric oxide. | Lime. | Magnesia. | Alkalies. |
|---|---|---|---|---|---|---|
| 1 | 54.2 | 45.8 | 0.0 | 0.0 | 0.0 | 0.0 |
| 2 | 52.5 | 43.5 | 1.2 | 0.2 | 0.0 | 1.2 |
| 3 | 50.5 | 48.2 | 0.4 | 0.5 | 0.7 | 0.4 |
| 4 | 55.8 | 43.2 | 0.9 | 0.1 | 0.2 | 0.6 |
| 5 | 54.2 | 41.3 | 0.4 | 0.6 | 0.4 | 2.3 |
| 6 | 52.0 | 42.8 | 1.1 | 0.8 | 0.0 | 1.9 |
| 7 | 51.6 | 43.4 | 1.7 | 0.5 | 0.4 | 1.1 |
| Average | 53.0 | 44.0 | 0.8 | 0.4 | 0.2 | 1.1 |

Some analyses of standard fire clays are given in Table IV and, as will be seen, the analyses of the silicious kaolins numbered 10, 11, 12, 19, 20, 21, and 22 compare well with them.

TABLE IV.[13]—*Analyses of standard fire clays.*

| Source. | Silica. | Alumina. | Ferric oxide. | Lime. | Magnesia. | Alkalies. | Ignition. |
|---|---|---|---|---|---|---|---|
| England (Stourbridge) | 65.10 | 22.22 | 1.92 | 0.14 | 0.18 | 0.18 | 9.86 |
| England (Brierley Hill) | 51.80 | 30.40 | 4.14 | 0.40 | 0.50 | 1.05 | 13.11 |
| Do | 69.25 | 17.90 | 2.97 | ---------- | 1.30 | ---------- | 7.58 |
| United States | 74.93 | 17.19 | 0.79 | 0.29 | 0.46 | 1.61 | 5.44 |
| Bohemia (Zettlitz) | 45.68 | 38.54 | 0.90 | 0.08 | 0.38 | 0.66 | 13.00 |

Analyses of the products of primitive peoples are given by Binns[14] from which the following have been selected:

TABLE V.—*Analyses of the products of primitive peoples.*

| Material. | Silica. | Alumina. | Ferric oxide. | Lime. | Magnesia. | Ignition. |
|---|---|---|---|---|---|---|
| Scandinavian pottery | 63.90 | 12.76 | 10.24 | 1.04 | 0.52 | 11.00 |
| Peruvian pottery | 67.04 | 10.83 | 10.17 | 3.24 | 0.28 | 8.07 |
| Etruscan pottery | 64.00 | 12.51 | 8.00 | 3.51 | 1.83 | 10.15 |

The loss on ignition demonstrates that these products have been fired at a very low temperature. They are given in order to show the comparison with the clay materials used by the Igorots. Analyses numbered 36 and 37 of Table I are only slightly better than the material the analyses of which are given in the above table. Practically all of the native pottery, cooking pots, "pelones," etc., outside of Manila are made from ordinary brick clay.

Chemical analyses of clays to be used for commercial purposes, are fundamental and at the outset necessary, for without them the reconstruc-

[13] Cf. Bourry, 65.

[14] Loc. cit., 16.

tion of the final material would be next to impossible. Because of the variation needed in making different wares it is seldom that a single clay is used for the purpose of manufacture; as a rule, several are mixed together. One kind of clay by judicious admixture of other materials is often adaptable to the manufacture of several varieties of wares. A practical potter, if he has a complete knowledge of the chemical composition of a clay, is able to mix different varieties and materials to suit a given purpose; that is, a chemical analysis shows him what ingredients must be added or removed to give a desired result. In itself, a chemical analysis does not show whether or not a clay is useful for a given purpose, for of the impurities in a clay some are easily melted, others are infusible, some are plastic and others are brittle, and slight differences in the plasticity, tensile strength, shrinkage, fusibility, color, etc., which are not controlled by the chemical composition, may very largely affect the commercial value of a clay.

*Plasticity,* that common property of all clay to form a moldable mass when wet, varies with different samples, forming an entire series, from those of low to the ones of very high plasticity. This property can not be inferred from the chemical analysis. Up to a certain point there is a coincidence of plasticity and bonding power and several of the other physical properties stand in close relation to the former. Manufacturers, as a consequence, carefully study the means of changing the degree of plasticity of clays; those which are commonly known are: The reduction by adding sand or less plastic clay, while materials of too low plasticity may often have this property increased by washing and thereby removing a part of the sand. Rohland [15] gives the following:

A. The ways of increasing the plasticity of clays: First, by contact with spring or river water, by means of which colloids are formed by hydrolysis. Thus silicic acid, aluminium, and iron hydroxides are produced. The action is expedited by fine grinding. Because the hydroxyl ions resulting from the hydrolysis tend to decrease the plasticity, pure water is not suitable for the above purpose, but owing to the acid fermentation of the organic constituents present, spring or river water, assisted by the organic matter of the clay or substances added intentionally, neutralize the action of the hydroxyl ions. Second, by lowering the temperature which has also to do with the colloids of clay. The effect is a very slow one. Third, by the addition of colloids and organic substances like dextrin, tannic acid, catechu, etc.

B. The ways of decreasing the plasticity, as: First, by the addition of hydroxyl ions, lime water being the cheapest reagent for this purpose. If the concentration of the hydroxyl ions of the lime water is too low for some clays, it may be increased by the addition of sodium hydroxide solution or any strong base combined with a weak acid. The latter class is represented by phosphates, silicates, etc. Neutral salts like sodium chloride, Glauber's salt, magnesium chloride, etc., appear to be indifferent. Borax weakens the effect of the hydroxyl ion and potassium carbonate strengthens the action. Second, by raising the temperature. Just as gelatin, agar-agar, etc., liquefy on heating to a certain

[15] *Sprechsaal* (1906), **42**, 1371; *Chem. Abstracts* (1907), **1**, 90.

temperature, so increased temperature causes clay to "run" and hence decreases plasticity. It appears likely that the organic constituents of clay cause this liquefaction as soon as a certain limiting temperature has been exceeded. The increase in temperature may be brought about mechanically by stirring.

There is no uniform way of determining plasticity. Some workers employ Bischof's method of forcing the moist clay through a die and measuring the distance it projects; others use the Vicat needle,[16] the method of Grout,[17] etc. There is a certain degree of relationship between the plasticity and the amount of water necessary to be added in order to form a workable paste. A fine-grained clay usually requires more water and as a rule is more plastic than one which is coarse. In the experiments recorded in Table VI water was added until the Vicat needle showed normal consistency, the water being afterwards determined by allowing the sample to air-dry.

*Tensile or breaking strength* is the resistance to rupture which is offered by the air-dried clay. This is an important factor to be determined in order to know the amount of nonplastic material that can safely be added and the sample still resist the shocks and strains in handling to which it is always subjected in the process of manufacture. This may be determined on any standard machine such as is used for the same purpose in cements. In carrying out the test the tempered clay is molded into briquettes, just as is the case with cement, the briquettes having a cross section of 6.45 square centimeters (1 square inch) when molded. They are allowed to dry, first in the air, then at 100°; then placed in the testing machine and a uniformly increasing load gradually applied so as not to produce a shock, until they break. Care must be exercised in placing the briquettes in the machine to prevent all cross strains from improper centering, and from other causes. Theoretically, a briquette should break across its smallest cross section, but failure to take any of the above precautions may result in anything but this.

*Shrinkage* is of two kinds—that which occurs in the air after the clay has been molded in a wet condition and that which takes place during the operation of burning. Both of these quantities vary greatly and are very useful in estimating the value of the raw material. The decrease of volume in the air is due to the drawing together of the particles, when the water added to afford a workable mass evaporates. Even in the same clay, this factor is often somewhat variable in proportion to the pressure given the material in molding. The amount of shrinkage of a clay upon burning depends not only upon the quantity of volatile constituents such as organic matter, water of constitution, carbon dioxide, etc., but also upon the texture of the clay and the temperature at which it is burned. Some clays containing high percentages of calcium and magnesium carbonates, even expand during certain stages

[16] Langenbeck, Karl: Chemistry of Pottery, Easton, Pa. (1895), 19.
[17] *Journ. Am. Chem. Soc.* (1905), **27**, 1037.

of the process, although they show normal shrinkage at other periods during the burning. Many clays shrink to such an extent that they warp, crack, or blister when burned. When the fire shrinkage is large, other substances of small or no fire shrinkage must be added. It is also necessary to know the air shrinkage in order to estimate the size of a mold necessary to give a finished product of given dimensions.

The shrinkages expressed in Table VI are given in per cent of the length of the briquette when freshly molded. The clays were all burned at a uniform temperature of about 1,100° C. (slightly above the melting point of gold), which is well above that at which all water of constitution passes off.

*Fusibility* is either increased or decreased by each constituent of a clay. Fire clay is practically pure aluminium silicate together with silica, and it will bear intense heat without melting. The presence of different quantities of iron alone varies the fusibility of the clay and therefore the use which can be made of it. The less the iron content the more refractory the clay. Other common fluxing materials are magnesia, lime, sodium and potassium compounds, and I have arranged them in the order of their fluxing power. The presence of any of these with the iron helps to form a flux and greatly to lower the fusion point. For example, if more than 2 or 3 per cent of lime or potash is present in a clay, good brick will not result as these substances cause the bricks to run into glass while they are being burned. The fusion point of a clay can best be determined by means of a pyrometer. It may also be satisfactorily judged by comparison with test pieces of known composition (standard Seger cones),[18] etc. The elaborate work on the composition and fusing point of Seger cones will be of assistance in deciding the fusibility of a clay from its analysis, as well as in actual comparative tests made by placing cones and clay side by side in the furnace. Cone number 1 melts at 1,150° and cone number 20 at 1,530°. The difference between any two successive numbers is 20° and the highest number is 36; this cone is composed of absolutely pure kaolin. The temperatures usually obtained in porcelain furnaces lie between the melting points of cones numbered 1 and 20.[19]

[18] Reis, H.: *U. S. G. S., P. P.* (1903), 11, 24; Bourry, E.: *Loc. cit.*, 396.

[19] The following data taken from Bourry's "Treatise on Ceramic Industries" give an idea of the numbers of the Seger cones which are used in various potteries:

| | | |
|---|---|---|
| Muffle firing for decoration | 0.022 to | 0.010 |
| Burning fusible bodies | .015 to | .01 |
| Burning slightly fusible bodies | 1 to | 10 |
| Stone ware burning | 5 to | 10 |
| Burning the body for fine faïence | 3 to | 10 |
| Burning the glaze for fine faïence | .010 to | .01 |
| Burning fire-clay ware and porcelain | 10 to | 20 |

The tests from 20 to 36 are used only in experiments for fusibility. The work of Simonis, *Sprechsaal*, 6, 71, *Chem. Abstracts* (1907), 1, 2166, shows that cones 20–25 melt within 18° of each other and that their use seems unnecessary.

The highest constant temperature obtainable in this country is at Zobel's pottery kiln in San Pedro Macati. In it a temperature of over 1,300° is attained, which is about the same as the highest temperature attainable in the muffle furnace of this Bureau. The kiln was placed at my disposal for experimental purposes and the temperatures of fusibility recorded in Table VI were determined there by comparison with standard cones and the temperature confirmed thermoelectrically. The fusing points marked *b* either lay above the temperature obtained with the furnace used, or a sufficient quantity of the sample was not at hand and therefore they were estimated from their analyses given in Table I, by comparison with a table of Seger cones and the fusion points actually determined, and by our general knowledge of fluxing materials.

*The color of a raw clay* is usually due to the presence of organic matter or of iron. In general, the former imparts a gray or black and the latter a buff or red color.

*The color of a burned clay* to a large extent depends on the proportion of iron and the state of its oxidization. Its presence makes the resulting product buff-brown or red. The more iron the clay contains, the deeper the red color. A quantity of iron as small as 1 per cent may impart a slight, yellowish tint. Clay which bears practically no iron burns white. In many cases the oxides of other metals are present and these often modulate the effect of the iron. The intensity of the color depends also on the temperature and the supply of air entering the kiln; in some cases it is possible to vary it from pink to reddish violet by changing these conditions and influencing the degree of oxidization. Sometimes these means are used to produce a standard or varied shade in wares. In terra cotta, especially, a certain percentage of iron is sought to give the finished product a definite and desired color. A certain manufacture is often known by the particular shade of the finished product. Titanium [20] renders clay yellow on burning. This is visible only when the material has a very low percentage of iron; when more iron is present the yellow is entirely obscured.

Below are given some physical properties of Philippine clays, including the plasticity, breaking or tensile strength, the shrinkage from the plastic condition in the air and with burning, and color.

[20] Attention is directed to the fact of the usual occurrence of titanic oxide in Philippine clay (see Table I). Its determination has not been carried out in every case, but not a single analysis has been made where it was not present and it usually occurs to the extent of from 0.4 to 1.3 per cent.

I have recently been interested in the titaniferous sands of these Islands and find them of almost universal occurrence. The commonest titaniferous minerals in these are ilmenite and rutile. These minerals occur only in small quantities in the rocks from which the sands are derived, for the sands represent large concentration; however, their universal distribution clearly indicates that they are the probable source of the titanium in clay.

TABLE VI.—*Physical properties of Philippine clays.*

| Clay number. | Water added to give a workable paste (per cent total weight). | Tensile strength (pounds per square inch). | | Shrinkage (per cent). | | Total. | Fusibility. | Color. | |
|---|---|---|---|---|---|---|---|---|---|
| | | Air-dried. | Burned. | Air. | Fire. | | | Air-dried. | Burned. |
| (a) | 14.0 | 181 | Medium | 7.5 | | | 1330 | Light gray | Pale violet gray. |
| 2 | 31.6 | | Low | 3.6 | 4.7 | 8.3 | [b]1720 | White | Very light grayish white. |
| 3 | 31.1 | 11 | do | 4.2 | 4.4 | 8.6 | [b]1740 | Cream | Rosy cream. |
| 4 | | | | | | | [b]1760 | | |
| 5 | 30.4 | | Low | 5.2 | 6.8 | 12.0 | [b]1680 | White | Creamy white. |
| 6 | 33.6 | | do | 3.6 | 4.0 | 7.6 | [b]1650 | do | White. |
| 7 | 31.6 | | do | 2.0 | 6.0 | 8.0 | [b]1650 | do | Pinkish white. |
| 8 | 27.9 | 63 | do | 4.8 | 1.9 | 6.7 | [b]1560 | Creamy white | Creamy white. |
| 9 | 24.9 | 43 | Medium | 3.2 | 13.6 | 16.8 | [b]1450 | Light buff | Pale lilac and rose. |
| 10 | 38.6 | | Low | 3.2 | | | [b]1690 | Creamy white | Light cream. |
| 11 | 31.3 | 63 | do | 8.2 | 0.9 | 9.1 | [b]1760 | White | Creamy white. |
| 12 | 36.0 | 12 | do | 1.5 | 4.1 | 5.6 | [b]1730 | do | White. |
| 13 | 24.0 | 46 | do | 4.7 | 0.4 | 5.1 | [b]1590 | Bluish white | Pale lilac. |
| 14 | | | | | | | [b]1410 | | |
| 15 | | | | | | | [b]1350 | | |
| 16 | | | | | | | [b]1300 | | |
| 17 | | | | | | | [b]1350 | Creamy white | |
| 18 | 32.2 | 72 | High | 1.1 | 14.7 | 15.8 | 1150 | Smoky creamy white. | Pale reddish chocolate. |
| 19 | 35.5 | 52 | Medium | 3.7 | 3.4 | 7.1 | [b]1510 | Bluish white | Yellowish pale violet. |
| 20 | 23.0 | 45 | | 4.8 | 0.4 | 5.2 | [b]1535 | do | Very pale violet. |
| 21 | | | | | | | [b]1420 | | |
| 22 | | | | | | | [b]1490 | | |
| 23 | 21.0 | 67 | | 3.2 | 3.1 | 6.3 | [b]1360 | Grayish white | Pale gray lilac. |
| 24 | 27.6 | 58 | High | 2.0 | 16.7 | 18.7 | 1200 | Creamy white | Very pale reddish chocolate. |
| 25 | 24.0 | 160 | Medium | 11.5 | 6.1 | 17.6 | [b]1500 | Dark cream | Violaceous pale gray.[c] |
| 26 | 25.5 | 171 | do | 11.6 | 5.1 | 16.7 | 1350 | Bluish gray | Gray lilac.[d] |
| 27 | 20.0 | 187 | do | 8.2 | 4.4 | 12.6 | 1350 | Light gray | Pale gray lilac.[d] |
| 28 | 23.8 | 176 | High | 10.0 | 3.8 | 13.8 | 1330 | Light slate gray | Reddish gray lilac. |
| 29 | | | | | | | 1310 | Light gray | |
| 30 | | | | | | | [b]1150 | Light ocherish gray. | |
| 31 | | | | | | | [b]1290 | | |
| 32 | 26.5 | 131 | Medium | 12.5 | 11.9 | 24.4 | 1330 | Brown | Reddish chocolate. |
| 33 | | 180 | High | 10.0 | 1.8 | 11.8 | 1200 | Light brown | Do. |
| 34 | 24.6 | 78 | Medium | 4.4 | 9.8 | 14.2 | [b]1370 | Buff | Do. |
| 35 | 24.3 | 77 | Below medium. | | | 8.0 | [b]1270 | Dark ocher | Very pale reddish ocher. |

[a] Given on page 415.
[b] Estimated.
[c] Some pieces decrepitate upon burning
[d] Decrepitates very badly upon burning.

It is realized that the field for the ceramic industries is very large and that the contribution of the data which I have collected is of small significance, but since all information regarding Philippine clays is meager,

these analyses may be of service in indicating the quality and the extent of the distribution.

McCaskey [21] in discussing the occurrence of clay in the Philippine Islands says:

White clays, or kaolin, have been found in the Provinces of Abra, Camarines, Ilocos Norte, Antique, Benguet, Cagayan, Isabela, Laguna, Marinduque, Masbate, Pampanga, Pangasinan, Albay, Romblon, and Zambales.

Red clays, from which natives make large amounts of pottery for local use, are found in almost every province in the Islands.

Fire clay has been found in the coal beds and may afford a profitable industry in the future.

Red bricks are made in large quantities in Bulacan, Capiz, Rizal, Ilocos Norte, Isabela, Marinduque, Masbate, and Pampanga.

Not much information is available regarding the magnitude of these deposits in Luzon; but the geologists report some of them to be large. Ickis [22] says:

In the Pajo Arroyo about 3 miles west of Los Baños and 1½ miles from the lake occurs a deposit of white clay which at present is being mined, sacked, and carried on the backs of natives to the Los Baños road; thence it is carted to Los Baños and shipped to Manila. All of the clay contains brown, iron-stained streaks, but below the first 2 feet the percentage of iron-stained material is very small. For a depth of 2 feet the clay contains some organic matter, besides a considerable percentage of iron, and is very plastic. The firm, white clay below varies greatly as regards plasticity. Most of the material exposed in the various holes possesses this valuable quality to a limited extent only, but one pit on the west side of the arroyo furnishes a pure, white clay highly prized by the workmen, which is much more plastic. Sample number 10, taken from the largest pit on the east side of the arroyo, represents the first class while number 7 is a sample of the more plastic clay.[23]

It was impossible for me to determine the extent of this bed of clay, owing partly to the limited time at my disposal and partly to want of exposures or extensive development work, but from surface indications the deposit seems to be large.

A study of Table III plainly shows that if deposits of sufficient magnitude warrant the establishment of porcelain factories, these kaolins can be recomposed by judiciously selecting and combining the clays with other materials to give the desired results. For example, if 70 per cent of specimen number 2, 20 per cent of feldspar ($K_2O \cdot Al_2O_3 \cdot 6SiO_2$) and 10 per cent of flint ($SiO_2$) were to be mixed together, and the result calculated, which would be obtained after the expulsion of the water and other material lost on ignition, we would obtain the following composition:

| Silica. | Alumina. | Iron. | Lime. | Magnesia. | Alkalies. | Titanic oxide. |
|---|---|---|---|---|---|---|
| 58.3 | 34.8 | 0.87 | 0.13 | 0.0 | 4.90 | 1.07 |

[21] *Fifth Annual Report of the Mining Bureau*, Manila (1904), 35.
[22] *Sixth Annual Report of the Mining Bureau*, Manila (1905), 58.
[23] The analyses are given under the same numbers in Table I.

which is almost identical with that of Meissen porcelain, given by Binns [24] as follows:

| Silica. | Alumina. | Iron. | Lime. | Magnesia. | Alkalies. |
|---|---|---|---|---|---|
| 58.5 | 35.10 | 0.80 | 0.30 | Trace. | 5.00 |

The common clays of Luzon are already used in several places in the manufacture of brick and crude pottery. For example, the brick-kilns at Mandaloyon and the one near San Pedro Macati, on the Pasig River near Santa Ana, each of which employs from ten to twenty laborers, turn out from one to three thousand bricks a day per kiln. Sample number 33, Table I, is an analysis of the clay used in Mandaloyon. No sand is added to it before molding, but the whole bank is broken down, mixed by the tread of carabaos, and used for the bricks. This makes the composition slightly different from the analysis given, but tests of the shrinkage and tensile strength show that its physical properties remain almost unchanged.

At present there is no fine pottery being made on this island. There is a factory near Manila which manufactures plates, cups, saucers, bowls, etc., and for these about 20 tons of the good Laguna kaolin are used every year.

The kaolin from Calamba employed in this pottery is too plastic when used alone, so it is recomposed by mixing with two varieties from Bulacan and Ilocos Norte Provinces, respectively. Experiments are now being made with Mariquina clay. The quartz used is picked from the gravel which is being dredged from the Pasig River near by; the asbestos which is placed in a layer between the plates in burning is from Zambales Province. It is of very poor quality, probably a much better variety may be obtained from Ilocos Norte.[25] The ware is dipped once for the siliceous glaze before it is burned. The breakage is small, not exceeding 2 or 3 per cent during the molding, drying, etc., and 4 or 5 per cent during the burning. Some of the ware is decorated in simple designs. It is difficult to describe the final product, which is quite similar to the English Dolton ware. This establishment employs eight men and the output is about 5,000 pieces per month. Formerly this ware had a large sale in Manila, but now is sold mostly in the provinces. There are two men still engaged in bringing kaolin from Laguna Province to the Manila market. The two sources are near Calamba and Los Baños from which are brought about 75 or 100 tons per year, respectively, it sells at wholesale in Manila for from ₱23 ($11.50, United States currency) to ₱32 ($16, United States currency) per ton. It is usually bought in 10-pound balls and finds its principal purchasers among the Chinese of Binondo, who make of it a sort of whitewash. The retail price varies with the supply from 25 centavos (12½ cents, United States currency)

[24] Ceramic Technology, London (1897), 19.

[25] Smith, W. D.: *This Journal, Sec. A, Gen. Sci.* (1907), **2**, 145.

a ball in the dry season to 40 centavos (20 cents, United States currency) during the rains, the higher price being due to the difficulties encountered in transporting the clay to market. These may be judged from an account of the working of Calamba clay given by Señor de la Rosa. He says that the clay is dug and carried on the backs of natives about 7 or 8 kilometers to the barrio of Bucal where the women make it into balls. When 500 to 1,000 of these are ready they are loaded into *bancas* and taken about 4 or 5 kilometers to Calamba where they are transferred to a casco and brought under tow to Manila.

The depth of the kaolin at Calamba has not been investigated, for after digging down about 2 meters it becomes too hot [26] to allow further penetration and then the washing of the rain fills up the hole. The superficial exposure is about a hectare. This kaolin has been used to some extent as a fire clay, for example, to repair the brickkiln at San Pedro Macati and the furnace of the glass factory. Señor Varcena at the school in Sampaloc has made some fire bricks and crucibles of good appearance from this clay.

As the price of building materials of all kinds is very high and shows little sign of decreasing, the demand for clay products of this nature is sure to increase. Many which are now in use can be replaced entirely by manufactures from local clays, if their preparation is taken up and placed upon a commercial basis. The tests of clays here reported should aid in the selection of suitable localities and in the finding of proper material for the development of these industries.

## RADIOACTIVITY.

In carrying out a series of experiments to ascertain the cause of the abnormal amounts of radioactive emanations contained in the air of cellars and caves, it was demonstrated by Elster and Geitel [27] that such emanations were not of spontaneous origin, but rather came from the soil and clay. They proved [28] that the air removed by simple suction from the soil was charged with active emanation and that its activity actually exceeded that of the air of cellars and caves. This activity is either a universal property of the air of the ground independent of the nature of the soil, or it is the result of a certain amount of primarily active substance contained in the material of the soil itself. Elster and Geitel have shown the latter assumption to be the only tenable theory. They found [29] that clay dug from their garden, introduced into their apparatus, after three days had reached a constant maximum value of about three times the normal. They considered that most of the

[26] The Los Baños springs are thermal.
[27] *Chem. News* (1903), **88**, 29.
[28] *Phys. Ztschr.* (1902), **3**, 574.
[29] *Ibid.* (1903), **4**, 522; *Chem. News.* (1903), **88**, 30.

conductivity observed in the gas was due to a radioactive emanation which diffused from the clay into the air in the vessel. They [30] say:

> It did not matter in this experiment whether the earth was in the moist condition in which it was removed, or whether it was introduced underneath the bell-glass after protracted drying; after the lapse of eight months no decrease of activity was apparent in the material.

In another experiment several substances were placed one-half meter in the earth, after four weeks they were dug up and the potter's clay, which in the beginning was inactive, was unmistakably active. The other substances used were still inactive. This shows that clays also have induced activity. Elster and Geitel found at different places considerable difference in the radioactivity of clays, it being invariably less near the sea.

The conductivity in the gas above the clay in the case already cited has been calculated [31] to be the same as that produced by the emanation from $7.10^{-10}$ grams of radium. Taking the density of clay as 2, this corresponds to about $10^{-13}$ grams radium per gram of clay. This has been calculated to be not greatly different from the amount of radium necessary in the earth to emit sufficient heat to compensate for the loss by conduction and radiation. On the basis of this Rutherford [32] expresses it as his opinion that the present rate of loss of heat of the earth might have continued unchanged for long periods of time.

I have examined several different specimens of the clays of Luzon, namely, numbers 8, 12, 32 and 33, by means of the leakage apparatus and all efforts failed to discover a trace of primary radioactivity in the material. The apparatus was of the general type of instrument used by Elster and Geitel,[33] Mache and Meyer,[34] Bacon[35] and other workers in their investigations of the radioactivity of ordinary materials. (See Pl. I.)

Three methods of determination were used in each case. One portion of the clay amounting to 10 grams was put immediately in the measuring chamber and the fall of the charged gold leaf observed for a period of hours; another was digested with acid in an Ehrlenmeyer flask, for some time tightly stoppered and allowed to stand. A third portion was fused with sodium carbonate, slaked in water, neutralized with hydrochloric acid and tightly stoppered in an Ehrlenmeyer flask. After one month these Ehrlenmeyer flasks in turn were connected in circuit with the apparatus and air was sucked through the solution so

[30] *Chem. News* (1903), **88**, 30.
[31] Rutherford, E.: Radioactivity, Cambridge, Eng. (1905), 507.
[32] *Ibid.*, 496.
[33] *Phys. Ztschr.* (1904), **5**, 321.
[34] *Monatsh. f. Chem.* (1905), **26**, 596.
[35] *This Journal* (1906), **1**, 435.

that any emanation would be drawn with it into the apparatus. In all cases excepting one, the air leak was perfectly normal for a period of hours, being identical with that produced by the natural activity of the air. In the first experiment with clay number 32 the conductivity was observed to be nearly double for a period of two hours, when the increase fell away.

The apparatus was sufficiently sensitive as is shown by test experiments with a sample of black uranium oxide (Kahlbaum) and one of pitchblende from Joachimthal which contained 26 per cent of uranium. One gram of the oxide was in turn uniformly spread over the bottom of platinum containers of various sizes, from a platinum crucible the bottom of which is 2 centimeters in diameter to a dish 4.5 centimeters in diameter and put immediately in the electroscope jar. The rate of fall in these was from 80 to 107 scale divisions per minute, 4,800 to 6,420 per hour, depending on the thinness of the layer of powder. Similarly, the rate of fall for one gram of the pitchblende varied from 100 to 203 scale divisions per minute, 8,000 to 12,180 per hour, depending on the spreading. The larger of these rates in each case is about the same as that obtained by Bacon[36] who used a dish of 4 or 5 centimeters diameter as the container in his experiments.

These numbers are not necessarily the maximum value because of the unavoidable absorption of the emanation at the surface of the powder, but with reasonably large spreading surface and working under constant conditions, the results are roughly comparable. The greatest activity of pitchblende yet observed is about five or six times that of uranium, and when they are considered with reference to the uranium content, approximately, that is the relation which exists between the above samples. By dissolving a mineral and then setting it aside in a closed vessel, the amount of emanation present reaches a maximum value after a month's interval. This was done with a gram of the pitchblende, the emanation being drawn into the apparatus by sucking air through the solution and a rate of fall of 640 scale divisions or 38,400 per hour was obtained as the average of eight closely agreeing readings under different chargings. The apparatus therefore was so sensitive that this pitchblende gave a rate of fall of the gold leaf more than 12,000 times as fast as that produced by the leakage through normal air.

From the work of Elster and Geitel the conclusion may be drawn that no primary radioactivity can be present in the above samples of Philippine clays, since they suffered no diminution in eight months. If our clays contained primary radioactive bodies this effect would have been noted since the samples were all investigated in less than eight months from the time they were taken. An extremely small amount of induced

[36] *Ibid, Gen. Sci., Sec. A* (1907), **2**, 124.

radioactivity was observed in clay number 32, while a certain amount might have been lost from the other samples during the time intervening between the taking of the sample and its examination in the laboratory. However, it seems more probable that there may be practically no radioactive bodies in these Islands, for two reasons, first, according to Elster and Geitel, very little radioactivity exists near the sea and, second, matter dissociates under the influence of radiant energy. The tropical sunlight affords opportunity for the maximum effect of the latter. Le Bon [37] calls attention to the fact that radiant energy falling upon matter causes it to dissociate, and if it is of sufficient intensity to heat the substance it also causes an expulsion of a small quantity of the radioactive elements produced by the dissociation. The action of the intense tropical sunlight for centuries on the various deposits occurring here may be accountable for the almost entire absence of radioactivity in these Islands. In support of this suggestion attention is called to the work of Ramsay and Spencer [38] where the "fatigue of metals," a perhaps comparable phenomenon, is produced by the action of intense light. It should also be remembered that Bacon [39] found no radioactivity in the waters of the crater lakes of Taal Volcano.

[37] *Compt. Rend. Acad. d. sc.* (1906), **143**, 647.
[38] *Philosophical Mag.* (1906), **12**, 402.
[39] *This Journal, Gen. Sci., Sec. A* (1907), **2**, 115.

# ILLUSTRATIONS.

PLATE I. Leakage apparatus used in examining several different specimens of the clays of Luzon (Cf. p. 433).

FIG. 1 (in text). Section showing the characteristic breaking down in the formation of residuary clay deposits.

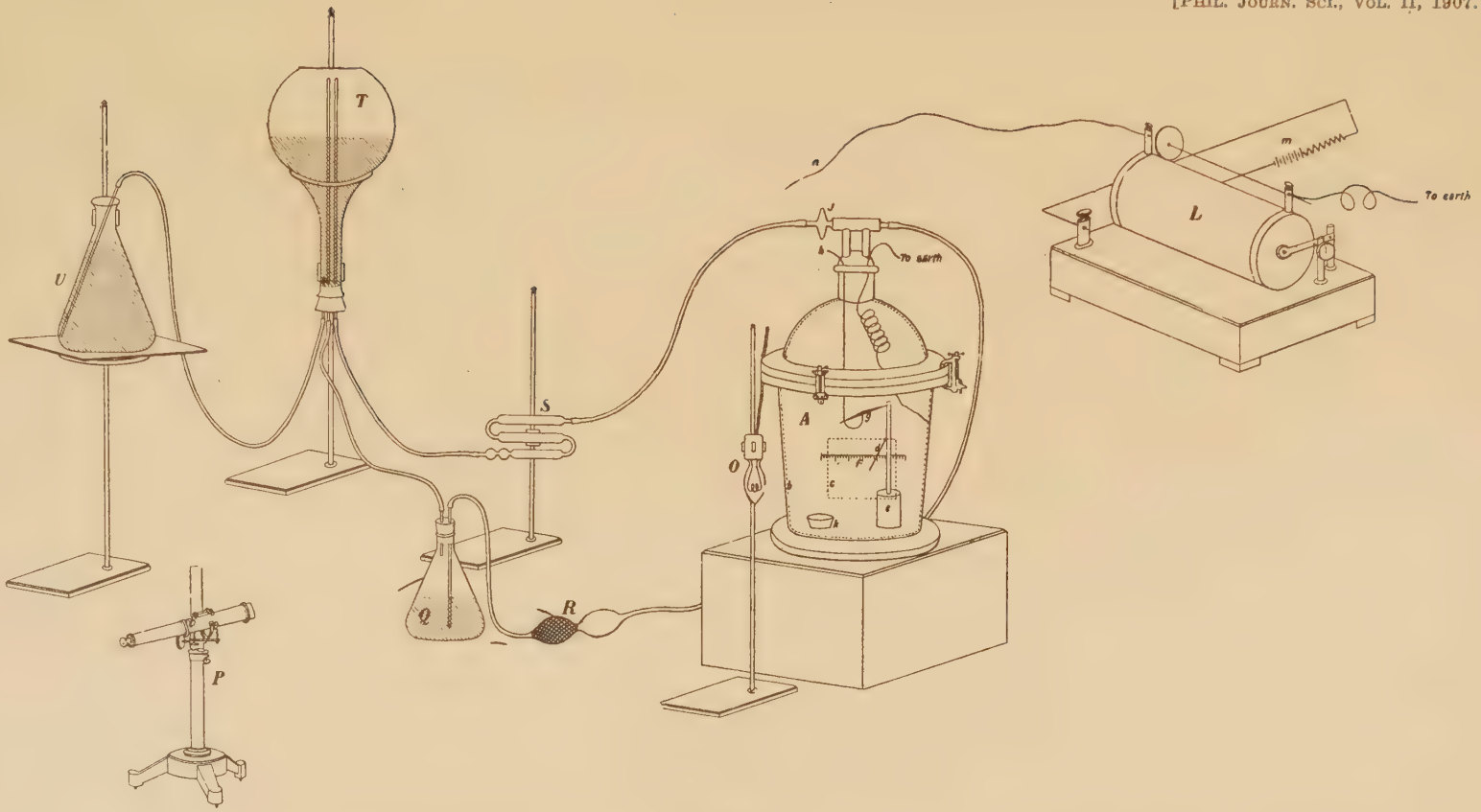



PLATE I.

LEAKAGE APPARATUS USED IN EXAMINING SEVERAL DIFFERENT SPECIMENS OF THE CLAYS OF LUZON.

A, An anaërobic jar fitted up for the measuring chamber. *b*, Tin-foil lining connected to earth. *c*, Observation hole in the lining. *d*, Gold-leaf electroscope. *e*, Insulating base. *f*, Scale, made by photographing an ordinary meter stick. *g*, Magnetic needle. *h*, Wire for charging the gold-leaf electroscope and for supporting the magnetic needle which may be brought into contact with the metallic strip (*i*) by the influence of an ordinary magnet without the apparatus. *i*, Insulated metal strip supporting the gold leaf. *j*, Stopcock for opening or closing the measuring chamber. *k*, Dish containing phosphorus pentaoxide. L, Charging apparatus. *m*, Five or ten accumulators. *n*, Charging point. O, Incandescent light for illuminating the scale. P, Reading telescope. Q, Receptacle for the solution of the substance to be investigated. R, Bulb with a valve. S, Calcium chloride drying tube. T and U, Pressure equalizers.

# COMMERCIAL UTILIZATION OF SOME PHILIPPINE OIL-BEARING SEEDS: PRELIMINARY PAPER.

By George F. Richmond and Mariano Vivencio del Rosario.
(*From the Chemical Division, Bureau of Science, Manila, P. I.*)

## INTRODUCTION.

The coconut is the best known and most widely distributed oil-producing seed of all tropical or semitropical countries and it is the only representative of its class that has assumed any commercial importance in the Philippines. However, a number of wild or semicultivated plants are found here which help to meet the local demand for vegetable oils, in the various uses to which oils are usually applied. Many of these oil seeds and nuts, or the oils which may be extracted therefrom, probably would find a ready market for use in some form if they were produced in commercial quantities and the uses for which they are best suited determined; therefore, it appeared well worth the trouble to examine a number of the local products and to begin extended investigations on the best methods of their commercial utilization. As a careful study of the properties of oils which are to compete with those already in use is necessary, such a work obviously must be one which will occupy a fairly long period of time. This paper will give a few preliminary observations which later will be extended.

The local use of a given commodity is not always that for which it is best adapted. In the case of fatty oils, questions of expediency rather than suitability usually govern their local application. Many vegetable oils and fats are employed as food and for illumination, when it is evident that they are much better suited for other purposes; furthermore, the valuable therapeutic properties claimed for certain of these products remains to be determined.

## VEGETABLE OILS.

### PRINCIPAL USES.

The following classification of oils, based on their leading practical uses, is adopted from C. R. Alder Wright.[1] The first and most important is alimental, including the expression or extraction of cooking fats and oils, the addition of oils as food preservatives, and the manufacture of

[1] Fixed Oils, Fats, Butters and Waxes, Lond. (1903), 359.

edible products. Formerly, and more particularly in temperate climates, animal fats and oils, such as lard, suet, butter fat, etc., were almost exclusively employed, but within comparatively recent times vegetable oils and fats have come into more general use for the above purposes. In some cases a taste for the new products must be created before they are generally adopted, but there seems to be no question as to the ease with which they are digested or as to their relative nutrient value.

The second use of oils is for illumination; that is, for burning in lamps and for candle making. Excepting in remote places where petroleum products are excluded because of their greater cost, the introduction of hydrocarbon oils for illumination and fuel has practically superseded the use of those from vegetable or animal fats. According to Tavera [2] a great variety of vegetable oils is used throughout India and the Philippines for lighting purposes, and the latter observation may be confirmed by anyone traveling in the provinces of the Philippines.

The third great application of oils is for soap manufacture. Most vegetable oils are well adapted to this purpose and have long been employed in the soap industry. Those most largely used are palm-nut, coconut, olive, cotton-seed, linseed and castor oils.

The fourth use is for the manufacture of paints, varnishes, linoleum, printers' inks, etc., and for this purpose linseed, certain nut oils, and Chinese wood oil (tüng oil) are employed.

Fifthly, there are miscellaneous applications in the arts and trades, these include lubricants, leather, cloth and textile dressings, employment in textile dyeing and in making printing inks, in the manufacture of perfumes, sealing wax, fly paper and other minor articles.

*A partial list of Philippine oil seeds.*[3]

| Botanical name. | English name. | Local name. |
|---|---|---|
| 1. *Aleurites moluccana* Willd. | Candle nut | Lumbang or lumbang bato (T.). |
| *trisperma* Blanco | | Lumbang banucalag (T.). |
| 2. *Calophyllum inophyllum* L. | | Palo maria de la playa (Sp.); dinkalan (T.); bitaog (V.). |
| *wallichianum* Pl. et Tr. | | Palo maria del monte (Sp.); bitanhol (T.). |
| 3. *Ceiba pentandra* (L) Gaertn. | Tree cotton | Kapok (D.); boboy (T.); doldol (V.). |
| 4. *Entada scandens* (L) Benth. | Gilla nuts | Gogo (T.); balogo (P. and V.). |
| 5. *Pongamia glabra* Vent. | | Balik-balik (T.); butog (V.). |
| 6. *Anacardium occidentale* L. | Cashew nut | Kasuy (T.). |
| 7. *Caesalpinia bonducella* (L.) Flem. | Fever nut; bonduc seeds (Indo-Eng.). | Kalambibit (T.); dalugdug (V.). |
| 8. *Jatropha curcas* L. | Physic nut; curcus oil | Tuba (T.); kasla (V.); tañgantañgan (P.). |
| 9. *Sesamum indicum* L. | Sesame | Liñga (T.); loga (V.); lagos (P.). |
| 10. *Ricinus communis* L. | Castor bean | Tañgantañgan (P. and T.). |

[2] Medicinal Plants of the Philippines, Manila (1901).

[3] T.=Tagalog; Sp.=Spanish; V.=Visayan; P.=Pampanga; D.=Dutch.

DESCRIPTION AND LOCAL USES.

*Aleurites moluccana.*—This is locally known as *lumbang* or *lumbang bato* in Tagalog, meaning stony fruit, and it is identical with the English candle nut. A very common, large tree, cultivated throughout most of the Archipelago, but more especially in Laguna, Cavite, Tayabas, and Batangas Provinces. It is found scattered in the Provinces of Pampanga and Tarlac, but is unknown in Bataan and Zambales. The supply of this nut is greater than the present demand and frequently the trees are cut for firewood which, because of its resinous quality, is highly prized. The wood is also marketed in Manila for match timber. The tree bears a large, fleshy fruit containing two very hard-shelled seeds which resemble a fairly large hickory nut in size and appearance.

*Distribution.*[4]—"Everywhere in Oceanica and the Sandwich Islands, and also cultivated in India, South America, West Indies, etc. In the Sandwich Islands the manufacture of candle-nut oil is a considerable branch of industry, about 10,000 barrels being annually exported to Peru, Valparaiso, Mexico, California and New York." The seed yields from 60 to 65 per cent of oil by extraction with carbon bisulphide, ether or chloroform, and about 55 per cent by hydraulic expression at 500 kilos per square centimeter.

Semler [5] describes the candle nut as follows:

"A product of *Aleurites moluccana*, a tree which like the croton tree belongs to the family *Euphorbiaceæ*. Formerly the *Aleurites triloba* was understood to be a distinct species because of its three-lobed leaves, but all transitions from not lobed to lobed leaves are found on the same tree. *Habitat:* It stretches from the South Sea islands over the Malay Archipelago over India and Madagascar. It appears to live in heavy stands in the forests. It is abundant at 800 meters (2,650 feet) but disappears at 1,200 meters elevation. Its roundish fruits are about the size of a small apple and are contained in a thick, fleshy scale, containing one or two hard seeds about the size of a horse-chestnut. The fruit in its rough state is a purge. When it is roasted it loses its purging properties. Contains 60 to 66 per cent oil. When cold pressed the oil is colorless and of agreeable odor and taste. When hot pressed it is brown and of a disagreeable taste. It has for a long time been known as a drying oil.

"The natives of the South Sea islands roast the fruit out of the shell. The oil is used for lights and for painting. The pressed cake is mixed with water and put around trees to drive away insects."

*Philippine candle nut.*—One kilo of whole nuts from Cavite Province contained 660 grams of shell, and 340 grams of kernels, or 66 and 34 per cent of shell and kernel, respectively.

One kilo of whole nuts crushed and ground in an oil mill and cold pressed yielded 175.7 grams of light, clear oil, which equals 17.57 per cent calculated on the gross weight of kernels and shells. Calculated on the kernels alone the yield is 51.67 per cent. The physical and chemical constants of lumbang oil are given in Table II.

By far the most general local use made of lumbang oil is for painting bancas (canoes) and for treating timber intended for use in the water,

[4] Brant, W. T.: Animal and Vegetable Fats and Oils, Phil. (1896), **2**, 1.
[5] *Trop. Agr.* (1903), **2**, 517.

as it is thought to preserve such timber from the attacks of insects in addition to possessing decided drying properties. Practically all of the oil thus used is prepared and marketed in Manila. There are only a few places in the city where the oil is being expressed and the presses used are of the crudest description, consisting of blocks and wedges. I would estimate that each mill produces approximately 20 gallons of oil per month. This oil is sold in 5-gallon petroleum cans and brings one peso ($0.50, United States currency) per gallon.

The cold-pressed oil is of a light, amber color and of an agreeable odor and taste, but we do not know that it is used as food anywhere in the Philippines, although it is reported to be employed in the adulteration of coconut and olive oils here and elsewhere. However, this may readily be detected by the increased specific gravity of the sophisticated oil, if the adulterant is added to any appreciable extent.

Mr. Walker, of this laboratory, has worked out an approximate method for detecting its presence in coconut oil by the decreased solubility of the mixture in absolute alcohol, as follows:

Alcohol used=0.8025 specific gravity at 15.5° C.=0.7938 specific gravity at 26° C., about 98 per cent by volume.

Take 10 cubic centimeters oil and 30 cubic centimeters alcohol in a large test tube. Shake well and place in a water bath at about 90° until dissolved. The mixture should be stirred rapidly with a light thermometer to prevent globules of oil from settling to the bottom. Remove from bath and note the temperature at which oil begins to separate. The end point is when the liquid clouds sufficiently so that the thermometer can not be read when it is in the center of the tube.

TABLE I.—*Test for lumbang oil in coconut oil.*

| Coconut oil. | Lumbang oil. | Temperature. |
|---|---|---|
| *Cubic cm.* | *Cubic cm.* | *C.* |
| 10 | 0 | 41 |
| 9 | 1 | 44 |
| 8 | 2 | 47 |
| 7 | 3 | 50 |
| 6 | 4 | 54 |
| 5 | 5 | 56 |
| 4 | 6 | 59 |
| 3 | 7 | 62 |
| 2 | 8 | 64 |
| 1 | 9 | 67 |
| 0 | 10 | 69 |

This table gives only a rough approximation of the percentage of adulteration. A very pure, fresh coconut oil may read 44° C. or higher, but it may easily be distinguished from an adulterated oil by its light color, pleasant taste and odor. Another sample of lumbang examined read 79° C., which indicates that comparatively large variations from this table may be expected.

*Aleurites trisperma.*—Another species of candle nut, called *lumbang banucalag* in Cavite and *baguilumbang* in Tayabas, is entirely confined to the Philippines, where it is widely distributed, but not so abundant as the first variety. The tree is about 40 feet high, and the fruit matures in June and July. Both species are propagated by seed or by cuttings and are of very rapid growth. The oil expressed from the *Aleurites trisperma* is more viscous and darker colored than that from *Aleurites moluccana*. Locally it is used principally for painting boats. The seeds of this variety of candle nut are comparatively thin shelled and are easily crushed.

One kilo of unshelled nuts produced 357 grams of shells and 643 grams of kernels. One kilo of unshelled nuts, crushed and pressed, yielded 327.28 grams of oil or 32.72 per cent which corresponds to a yield of 50.9 per cent calculated on the kernels. The oil dries more rapidly than linseed oil or the lumbang bato previously described, and is so closely allied to the Chinese wood oil as to make its differentiation difficult.

A careful study of the drying properties of the two species of *Aleurites* oils found in the Philippines as compared with Chinese wood or tüng oil (*Aleurites* sp.) and linseed oil, is now being made in this laboratory. Considerable confusion and great variation in the recorded constants for the Chinese variety of *Aleurites* exist in the literature.[6] Certain observers name two varieties of trees producing Chinese wood or *tüng* oil and as this oil is considered of great value in the manufacture of varnishes and linoleum, the study which we have undertaken for the establishment of its similarity or identity with the oils furnished by the local species is important. The results are not ready for publication.

TABLE II.—*Table of oil constants.*

| Property. | Lumbang bato (*Aleurites moluccana*). | Lumbang banucalag (*Aleurites trisperma*). | Chinese wood[c] or tüng oil (*Aleurites* sp.). | Linseed[d] oil. |
|---|---|---|---|---|
| Specific gravity at 15° C | 0.925–0.927 | 0.9368 | 0.9425 | 0.9368 |
| Acid value (milligrams of potash per one gram of oil) | 2.115 | 2.150 | 4.547<br>4.568 | 3.18 |
| Saponification value (milligrams of potash per one gram of oil) | 193.5 | 200.3<br>200.5 | 189.3 | 186 |
| Iodine value (Hanus) | [a]150.2 | [b]158.5 | 155.7 | 179 |
| Maumené value | 100 | 86.2 | 105 | 103 |
| Refractive index at 60° C | 1.4648 | 1.483 | 1.5032 | 1.4687 |
| Hehner value | 95.54 | 95.79 | 94.32 | 94.43 |
| Melting point | —12° C. | 2 to 4° C. | 2° C. | |
| Solidifying point | —22° C. | —6.5° C. | —7.5° C. | —25° C. |

[a] Average 8 determinations.
[b] Average 4 determinations.
[c] Oil obtained on the Hongkong market.
[d] Pure oil obtained from expression of hand-picked seed.

[6] *Kew. Bull.* (1906), 117; *Bull. Imp. Inst.* (1907), **5**, 134.

*Calophyllum inophyllum* (*Palo maria*).[7]—A large, hardwood tree belonging to the family *Guttiferæ*, found along the sea shores throughout the tropics of both hemispheres. In the Philippines it is known as *palo maria de la playa* to distinguish it from *Calophyllum wallichianum*, the widely distributed form found in upland forests known as *palo maria del monte*. It has a beautiful, dark green, thick, fine-nerved leaf, 4 to 5 inches long, from whence is derived the name *Calophyllum* or *Schönblatt*. The fruit is the size of a walnut, with a fleshy rim containing a thin-shelled seed which incloses a hard, oily kernel. The fruit of the mountain variety is only two-thirds to three-fourths the size of that growing near the seashore. Each tree yields several bushels of nuts per year. There is no established industry, although in some localities the oil is expressed and used for lights.

Oil from the expressed seeds of *Calophyllum inophyllum* is called domba, and in Indo-English, improperly, laurel-nut oil. The kernels on extraction yield 70 to 75 per cent of a greenish-yellow oil. The oil is not servicable as an edible fat, since it contains a poisonous resin to which the color and odor are due. On the other hand, it finds application as a natural remedy in skin diseases and rheumatism, and it is used for that purpose in many districts of India; it is exported in considerable amounts from Travancore, particularly from Burma, and under the name of "udiloöl" it has been experimentated with in Europe for some time in the treatment of rheumatism.

"The seeds of *Calophyllum inophyllum*,[8] a forest tree widely distributed in the eastern tropics, furnish an oil known by various names (dilo, domba, pinnay, poon seed or tamanu oil); when mixed with pigments, this forms a paint that dries in twelve hours, without any previous boiling. Owing to the large yield of oil and the plentifulness of the trees in India, Ceylon, the Malay Archipelago and Java, and the South Pacific islands, etc., this oil appears likely to be an important article in the future."

"Domba oil[9] is obtained from the nuts of *Calophyllum inophyllum*. It is chiefly used as an embrocation for rheumatism, and for illuminating purposes. Domba oil is sold in Burma at four times the Calcutta price of castor oil, which it resembles." G. Fenler[10] has made a chemical examination of the oil from *Calophyllum inophyllum*. He describes it as greenish-yellow in color, of a bitter, pungent taste, soluble in all proportions in the usual solvents, but insoluble in absolute alcohol. The following values are recorded:

| | |
|---|---|
| Specific gravity at 15° C. | 0.942 |
| Reichert Meissel number | .13 |
| Acid value | 28.45 |
| Saponification value | 196 |
| Iodine value | 92.8 |

[7] Tavera: Medicinal Plants of the Philippines, Manila (1901), 38.
[8] Alder Wright, C. R.: Fixed oils, fats, butters and waxes (1903), 348.
[9] *J. Soc. Chem. Ind.* (1901), **20**, 624.
[10] *Chem. Ztschr.* (1905), 29, 15.

By treating with caustic soda the oil yields a greenish resin of semiliquid consistency, soluble in alcohol. The fatty acids consist mainly of palmitic, oleic and stearic. It is stated that the oil is also used in the manufacture of soap.

*Ceiba pentandra* (*kapok.*)—The cotton tree which furnishes the fiber used commercially for upholstering, under the Malayan name "kapok," is exceedingly common in cultivation along the highways, in all parts of the Philippine Islands. It is a somewhat thorny tree 40 to 60 feet high, with horizontal branches in whorls. The fruit is a pod 4 to 6 inches long, spindle shaped and filled with black seeds embedded in fine, silky hairs.

It is distributed throughout the tropics of the world. In Java a considerable industry exists in the products of this tree. The seed hairs are used for pillows, mattresses, sofas, etc., where their lightness, softness, elasticity and immunity from moths, makes them superior for the above-mentioned purposes. In Manila it is being used with excellent results for insulation.

The undecorticated seeds by extraction with ether yield 25.3 per cent of bland oil of a yellowish color and agreeable taste, and 20 per cent by a pressure of 450 atmospheres with the laboratory hydraulic press. Undecorticated, ground seeds are too difficult to press and the yield of oil is too low for economical milling.

The fertilizer analysis of extracted kapok seed meal which is given in Table III compares very favorably with the average composition of upland cotton-seed meal, which is used so extensively in the Southern States of North America. Experiments in feeding ground kapok seed to hogs, cattle and horses at the experimental station of the Philippine Bureau of Agriculture were favorable to its use as a stock food. The product much resembles ground linseed in food value.

The recorded physical and chemical constants of kapok oil are as follows:[11]

| | |
|---|---|
| Specific gravity at 15° C. | 0.9237 |
| Saponification value | 181 |
| Iodine value | 117.9 |
| Hehner value | 94.9 |
| Maumené test | 95 |
| Refractive index | 51.3° |

*Anacardium occidentale.*—This plant furnishes the *cashew nut* and is very common throughout the Archipelago, having been introduced from tropical America. The nut is a large, yellow, pear-shaped fruit, and contains a brown, kidney-shaped seed attached to one end of the fleshy part. Both the fruit and nut are edible, the latter, when roasted, having a very agreeable taste. The roasted kernel is said to be used in the adulteration of chocolate. The expressed kernel yields a sweet, yellowish

[11] Lewkowitsch, J.: Oele, Fette und Wachse, Braunshweig (1905), 2, 94.

oil. The nuts may be obtained in quantities in nearly all Philippine market places.

*Jatropha curcas.*—A shrubby tree 8 to 10 feet high, common throughout the Philippines, having been introduced from Mexico; it is cultivated for hedges in the towns and along the roadways. The seeds of this plant in shape and size are similar to a large, ground-nut kernel and yield from 30 to 40 per cent of a yellow oil. These seeds are called purging or physic nuts by the English and the expressed oil is the well-known curcas oil of commerce. According to Tavera [12] the oil is used for purposes of illumination in some parts of the Philippines and is exported to Europe to adulterate soaps and candles.

A recent examination of purging nuts from Lagos [13] gave the following results:

"The kernels constitute 66 per cent of the whole weight of the seeds. Extraction with ether of the desiccated seeds yields 52 per cent of a yellow oil of a faint, peculiar odor and a bland, nutty taste. The oil furnishes the following constants:"

| | |
|---|---|
| Specific gravity at 15° C. | 0.919 |
| Free acid value | 4.47 |
| Free acid calculated as oleïc acid | 2.25 |
| Saponification value | 204 |
| Iodine value | 99.1 |
| Ester value | 199.5 |
| Neutral oil | 97.76 |

Curcas oil has been examined previously by several observers whose results vary within limits given in the following table:

| | |
|---|---|
| Specific gravity | 0.919–0.925 |
| Free fatty acids (calculated as oleïc acid), per cent | .36–11.8 |
| Saponification value | 192–210 |
| Iodine value | 98–110 |

This oil belongs to the class of semidrying oils. It is employed in the manufacture of soaps and candles and also as an illuminant and lubricant, but because of its drying properties it is not well adapted for the last-mentioned purpose. It is a strong purgative and in India it is used medicinally.

Physic nuts examined in the laboratory gave 45 per cent of hulls and 55 per cent of kernels, the latter yielded by extraction with chloroform 63.05 per cent of oil, which corresponds to 34.65 per cent calculated on undecorticated seeds. Because of its purgative action the seed cake left after expression of the oil would be unsuitable as a cattle food. Its fertilizer value is given in Table III.

[12] Medicinal Plants of the Philippines, Manila (1901), 216.

[13] *Bull. Imp. Inst.* (1904), **2**, 170.

*Sesamum indicum*.—The black-seeded variety has been grown as a minor crop for many years in these Islands; the white-seeded, which produces a finer grade of oil, is found only where it was introduced by W. S. Lyons [14] of the Philippine Bureau of Agriculture. He reports very favorably on the possibility of culture in these Islands of this important oil-bearing seed.

*Ricinus communis* (castor-oil plant).—A weed universally distributed throughout the tropics of the world and more or less cultivated in temperate and subtemperate regions. It grows in waste places in and about towns throughout the Philippines, apparently seed producing throughout the entire year. This plant is entirely naturalized and grows wild in the Islands, although it is occasionally cultivated for ornamental purposes. In the provinces it is used medicinally, two or three plants frequently being found near the nipa houses of the poorer classes. It is not cultivated here on a commercial scale, the castor oil used in Manila and the larger towns apparently being imported from Europe. The plant thrives without cultivation in poor soils and is one of the commonest and most widely distributed species found in the Philippines, having been introduced by way of the Malayan region probably long before the Spanish conquest. The original home of the species presumably is Africa.

I can find no data regarding the methods of gathering the crop, but it is presumed that the capsules are picked by hand from time to time, as the seeds ripen throughout the year.

The following notes are abstracted concerning the castor-oil industry, from data compiled by Dougherty [15] of the United States Bureau of Statistics:

> First and most important is its use in connection with calico dyeing and printing, in the preparation of so-called "turkey-red oil" which is sulphuretted castor oil, a product soluble in water, possessing the important property of fixing aniline dyes. The second and probably the next most important channel of consumption is the drug trade. It is used in China as a cooking grease, as lard is used in America. It is used extensively in British India and other countries as an illuminant. Australia imported 769,000 gallons in 1898 and Cape of Good Hope 307,000 gallons in 1902 for the same purpose. The peculiar properties of this oil, which is heavy, viscous and non-drying, adapt it for lubrication purposes, as is well known. Heavy petroleum is used more extensively only on account of its greater cheapness. Its value as a lubricant is suggested by the fact that petroleum products adulterated with resin are now sold under the name "machine castor oil." Castor oil also has properties that adapt it as a leather dressing. Many minor uses may be mentioned such as its employment in the manufacture of sticky fly paper, and so-called "glycerine soap."
>
> *Process of manufacture.*—The equipment for a castor-oil mill is identical in its main features with that of mills for the manufacture of linseed, cotton-seed,

[14] Farmers' Bull. (1903), No. 7, 12.

[15] Year Book, U. S. Dept. Agr. (1905), 287.

or coconut oil; that is, the mechanical unit of production is the hydraulic press. Hulling and crushing the seeds is unnecessary. They are hand picked and submitted to hydraulic pressure either hot or cold. Two grades of oil are produced, the first for medicinal use, and the second for the various other purposes. One-half to one cent per pound difference in price exists between the two grades, 9 to 11 cents per pound being the prevailing price in the United States. The oil cake, called castor pomace, on account of its poisonous properties, has no food value, but it contains potash and phosporic acid, and is especially rich in nitrogen, therefore it is well adapted for a manurial. The high percentage of oil left in oil cake by commercial processes is said to prevent its rapid decomposition in the soil and thus to prolong its fertilizing effect. In some sections of the United States the castor pomace is highly regarded as a fertilizer for tobacco. In British India, where more of this product is made and used than in any other country in the world, it is much esteemed as a manure for potatoes, wheat, oats and corn. Good qualities of beans contain about 45 per cent of oil, but the yield extracted by manufacturing processes in the United States approximates only about 32 per cent. At this rate there is obtained 16 pounds (2 gallons) of oil and 34 pounds of pomace per bushel of 50 pounds of the beans.

The supply of the United States is almost entirely derived from two widely separated regions: the first, a few counties in Oklohama, Kansas, Missouri and Illinois, the second, British India, a country that has long held the monopoly of the commercial castor bean production of the world. Statistics show that probably three-fourths, and possibly four-fifths, of the castor oil manufactured in the United States is from imported beans. The maximum demand for this product in the United States is 1,000,000 gallons annually in round numbers.

British India is the only great castor bean producing country, the United States, England, France and Germany all deriving their supply from this particular source. The castor bean production in the United States has declined steadily for years, while the demand for its products has had a steady upward trend until, as above stated, practically the entire supply is now imported. Several reasons for this condition of things may be given. The castor plant being tropical in its origin must be acclimated in a country of late and early frosts, to which the plant is very susceptible, while the land is much more valuable for the growing or crops already adapted to the prevailing climatic conditions.

In the Philippine Islands we find the plant producing abundantly under natural conditions, therefore much may be accomplished under proper cultivation. Furthermore, any initial outlay in milling machinery would be unnecessary, as the product can be worked up in a coconut-oil mill. We might therefore be able to place on this market an oil for purposes of lubrication and illumination which would be nonedible and which could be produced as cheaply as coconut oil, now in general use. We are nearer to the Australian market than is British India, from whence the supply of castor oil is brought, but most important of all if we could supply the increasing demands of America and thus divert the large export trade from British India to the Philippine Islands, the result would warrant the exploitation of castor oil in the Archipelago.

TABLE III.—*Comparison of the fertilization value of some Philippine seed cakes with that of cotton-seed meal.*

| | Lumbang bato. | Lumbang banuca-lag. | Kapok. | Castor. | Palo maria. | Cotton seed. | Physic nut. |
|---|---|---|---|---|---|---|---|
| | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| Moisture | 8.189 | 8.480 | 13.67 | 8.64 | 6.248 | 7.50 | 9.91 |
| Total nitrogen | 6.464 | 3.968 | 5.21 | 4.80 | 2.68 | 6.37 | 2.14 |
| Nitrogen equivalent to ammonia | 7.852 | 4.818 | 6.326 | 5.83 | 3.254 | 7.75 | 2.60 |
| Total phosphoric acid | 3.355 | 2.292 | 2.798 | 1.75 | 1.006 | 2.65 | 1.33 |
| Available phosphoric acid | 3.280 | 2.183 | 2.741 | 1.55 | .964 | 2.45 | 1.25 |
| Potash soluble in water | 1.502 | 1.311 | 1.758 | 1.04 | 1.00 | 1.55 | 2.42 |
| Relative commercial value per ton of 2,000 pounds[a] | $27.67 | $17.51 | $24.61 | $19.77 | $13.83 | $26.76 | $11.22 |

[a] The valuation is based on the average market quotation on the unmixed ingredients used in the manufacture of commercial fertilizers.

# ERRATA.

Page 310 for **Osmoteron** read **Osmotreron.**
Page 342 for **faciolata** read **fasciolata.**

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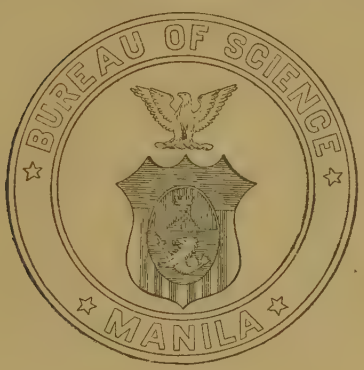


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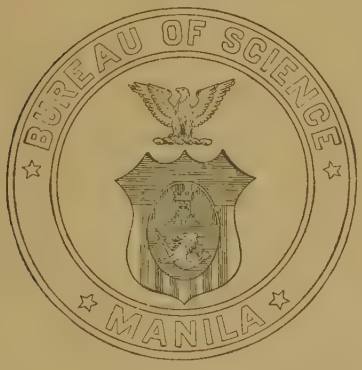


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OF THE

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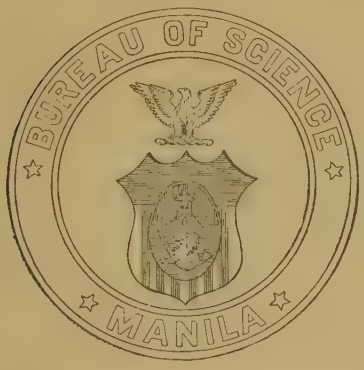


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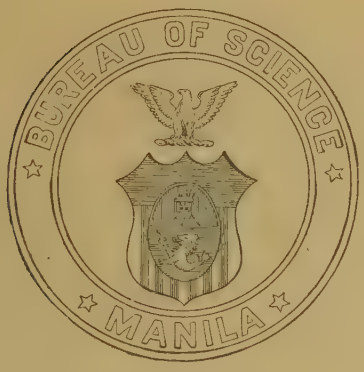


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CO-EDITORS

RICHARD P. STRONG, PH. B., M. D.
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OF THE

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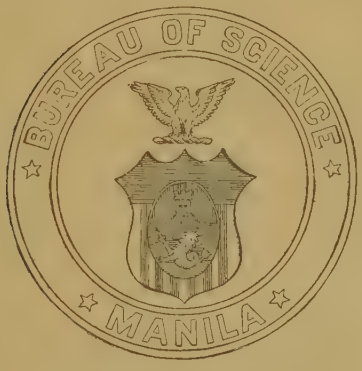


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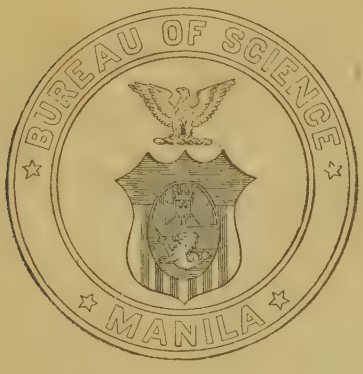


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[1] The first four bulletins in the ornithological series were published by The Ethnological Survey under the title "Bulletins of the Philippine Museum." The other ornithological publications of the Government appeared as publications of the Bureau of Government Laboratories.

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